Ambient Groundwater Quality of the Upper Hassayampa Basin: A 2003 - 2009 Baseline Study

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Maps by Jean Ann Rodine

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Arizona Department of Environmental Quality
Open File Report 13-03

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Thanks:

Field Assistance: Elizabeth Boettcher, Angela Lucci, Brent Mitchell, and Meghan Smart. Special recognition is extended to the many well owners who were kind enough to give permission to collect groundwater data on their property.

Photo Credits: Douglas Towne

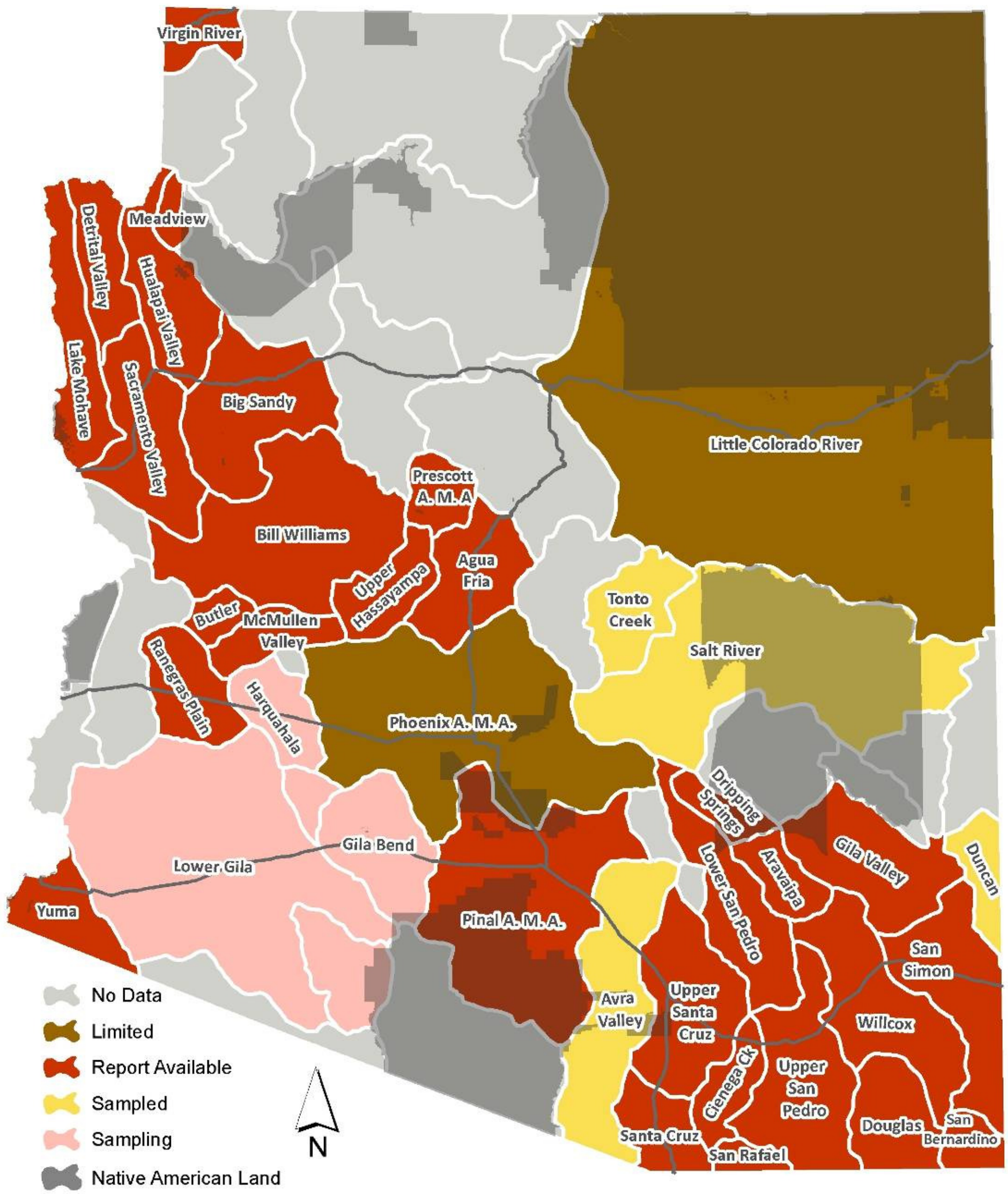
Report Cover: An unused aqueduct, the Leppe Wash flume, is located on the historic TK Bar Ranch along the Hassayampa River near Kirkland, Arizona. The inset photo shows the ML Windmill, the water tank of which also serves as a sign post along the rugged Wagoner Road that connects the communities of Kirkland Junction and Crown King. The cover collage was created by Phil Amorosi and Nancy Caroli.

Other Publications of the ADEQ Ambient Groundwater Monitoring Program

ADEQ Ambient Groundwater Quality Open-File Reports (OFR) and Factsheets (FS):

Upper Hassayampa Basin	OFR 13-03, 52 p.	FS 13-11, 4 p.
Aravaipa Canyon Basin	OFR 13-01, 46 p.	FS 13-04, 4 p.
Butler Valley Basin	OFR 12-06, 44 p.	FS 12-10, 5.p.
Cienega Creek Basin	OFR 12-02, 46 p.	FS 12-05, 4.p.
Ranegras Plain Basin	OFR 11-07, 63 p.	FS 12-01, 4.p.
Groundwater Quality in Arizona	OFR 11-04, 26 p.	-
Bill Williams Basin	OFR 11-06, 77 p.	FS 12-01, 4.p.
San Bernardino Valley Basin	OFR 10-03, 43 p.	FS 10-31, 4 p.
Dripping Springs Wash Basin	OFR 10-02, 33 p.	FS 11-02, 4 p.
McMullen Valley Basin	OFR 11-02, 94 p.	FS 11-03, 6 p.
Gila Valley Sub-basin	OFR 09-12, 99 p.	FS 09-28, 8 p.
Agua Fria Basin	OFR 08-02, 60 p.	FS 08-15, 4 p.
Pinal Active Management Area	OFR 08-01, 97 p.	FS 07-27, 7 p.
Hualapai Valley Basin	OFR 07-05, 53 p.	FS 07-10, 4 p.
Big Sandy Basin	OFR 06-09, 66 p.	FS 06-24, 4 p.
Lake Mohave Basin	OFR 05-08, 66 p.	FS 05-21, 4 p.
Meadview Basin	OFR 05-01, 29 p.	FS 05-01, 4 p.
San Simon Sub-Basin	OFR 04-02, 78 p.	FS 04-06, 4 p.
Detrital Valley Basin	OFR 03-03, 65 p.	FS 03-07, 4 p.
San Rafael Basin	OFR 03-01, 42 p.	FS 03-03, 4 p.
Lower San Pedro Basin	OFR 02-01, 74 p.	FS 02-09, 4 p.
Willcox Basin	OFR 01-09, 55 p.	FS 01-13, 4 p.
Sacramento Valley Basin	OFR 01-04, 77 p.	FS 01-10, 4 p
Upper Santa Cruz Basin (w/ USGS)	OFR 00-06, 55 p.	-
Prescott Active Management Area	OFR 00-01, 77 p.	FS 00-13, 4 p.
Upper San Pedro Basin (w/ USGS)	OFR 99-12, 50 p.	FS 97-08, 2 p.
Douglas Basin	OFR 99-11, 155 p.	FS 00-08, 4 p.
Virgin River Basin	OFR 99-04, 98 p.	FS 01-02, 4 p.
Yuma Basin	OFR 98-07, 121 p.	FS 01-03, 4 p.

These publications are available at: www.azdeq.gov/environ/water/assessment/ambient.html



Map 1. ADEQ Ambient Groundwater Monitoring Program Studies

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Abbreviations

amsl	above mean sea level
ac-ft	acre-feet
af/yr	acre-feet per year
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
ARRA	Arizona Radiation Regulatory Agency
AZGS	Arizona Geological Survey
As	arsenic
bls	below land surface
BLM	U.S. Department of the Interior Bureau of Land Management
CAP	Central Arizona Project
^{o}C	degrees Celsius
$CI_{0.95}$	95 percent Confidence Interval
Cl	chloride
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gpm	gallons per minute
GWPL	Groundwater Protection List active ingredient
HCl	hydrochloric acid
LLD	Lower Limit of Detection
Mn	manganese
MCL	Maximum Contaminant Level
ml	milliliter
msl	mean sea level
ug/L	micrograms per liter
um	micron
uS/cm	microsiemens per centimeter at 25° Celsius
mg/L	milligrams per liter
MRL	Minimum Reporting Level
ns	not significant
ntu	nephelometric turbidity unit
pCi/L	picocuries per liter
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SAR	Sodium Adsorption Ratio
SDW	Safe Drinking Water
SC	Specific Conductivity
su	standard pH units
SO_4	sulfate
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
UHA	Upper Hassayampa Groundwater Basin
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VOC	Volatile Organic Compound
WQARF	Water Quality Assurance Revolving Fund
*	significant at $p \leq 0.05$ or 95% confidence level
**	significant at $p \leq 0.01$ or 99% confidence level
***	for information only, statistical test for this constituent invalid because detections fewer than 50 percent

Ambient Groundwater Quality of the Upper Hassayampa Basin: A 2003-2009 Baseline Study

Abstract - From 2003-2009, the Arizona Department of Environmental Quality conducted a baseline groundwater quality study of the Upper Hassayampa basin located approximately 60 miles northwest of Phoenix. The basin comprises 787 square miles within Maricopa and Yavapai counties and had an estimated population of 10,479 in 2000.[4] The largest population center in the basin is the Town of Wickenburg; other communities include Congress, Groom Creek, and Wagoner. The basin is characterized by mid-elevation mountains and valleys. Low-intensity livestock grazing is the predominant land use and ranches sometimes have limited acreages of irrigated pasture for additional feed. The basin contains a large inactive copper mine, the Zonia Property located northwest of Wagoner.[4] Land ownership in the basin consists of federal lands (46 percent) managed by the U.S. Forest Service (25 percent) and the Bureau of Land Management (21 percent), State Trust lands (38 percent), and private land (16 percent). [3]

The basin is drained by the Hassayampa River, a tributary to the Gila River, which begins in the Bradshaw Mountains. The stream flows south until exiting the basin about five miles south of Wickenburg. The Hassayampa River is mostly intermittent but is perennial in its upper reaches and south of Wickenburg; some of its tributaries also have limited perennial stretches.[4] There are no surface water diversions or impoundments besides stock ponds within the basin as groundwater is used for all public water supply, domestic, irrigation, and industrial uses.

Groundwater occurs primarily in the basin-fill aquifer that is generally found in the southeastern portion of the basin. Composed of gravel, sand, silt, and clay, the basin-fill aquifer can yield up to several hundred gallons per minute. Smaller alluvial deposits are also found in valleys particularly along the Hassayampa River in the north-central portion of the basin. Lesser amounts of groundwater are found in the surrounding bedrock, especially along faults, fracture zones, and/or localized perched aquifers.[4,19] Most groundwater is used for public water supply, irrigation, and industrial (primarily dairy) uses; only minor amounts are used for stock and domestic purposes.[4]

Thirty-four sites (27 wells and 7 springs) were sampled for the study. Inorganic constituents and isotopes (oxygen and deuterium) were collected at each site while radon (17) and radionuclide (12) were collected at selected sites.

Based on these water quality sample results, groundwater in the basin is generally suitable for drinking water uses. Of the 34 sites sampled, 20 sites met all drinking water quality standards not including the proposed radon standard. Health-based, Primary Maximum Contaminant Levels (MCLs) were exceeded at nine sites (27 percent). These enforceable standards define the maximum concentrations of constituents allowed in water supplied for drinking water purposes by a public water system and are based on a lifetime daily consumption of two liters. [25] Constituents exceeding Primary MCLs include arsenic (1 site), gross alpha (5 sites), and nitrate (4 sites). Aesthetics-based, Secondary MCLs were exceeded at 13 of the 34 sites (38 percent). These are unenforceable guidelines that define the maximum constituent concentration that can be present in drinking water without an unpleasant taste, color, or odor.[25] Constituents exceeding Secondary MCLs include chloride (1 site), fluoride (4 sites), iron (2 sites), manganese (4 sites), sulfate (1 site), and Total Dissolved Solids (TDS) (8 sites). Of the 17 sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard while 8 sites (47 percent) exceeded the proposed 300 pCi/L standard. [25]

Groundwater in the basin typically has calcium or mixed-bicarbonate chemistry and is *slightly-alkaline*, *fresh*, and *hard* to *very hard*, based on pH levels along with TDS and hardness concentrations.[8, 11] Oxygen and deuterium isotope values at most sites appear to reflect the elevation at which the sample sites were located. Five samples that were depleted experienced little evaporation and are located in the Bradshaw Mountains. The other 29 samples were more enriched, suggesting the water from these lower elevation sites was subject to much greater evaporation.[9]

Groundwater constituent concentrations were influenced by recharge group and geology.[9, 16] Constituents such as temperature, pH-lab, sodium, potassium, chloride, fluoride, oxygen-18 and deuterium had significantly higher constituent concentrations at sites with enriched samples collected at lower elevations than at sites with depleted samples collected at higher elevations. (Kruskal-Wallis test, $p \leq 0.05$). Constituents such as temperature, sodium, sulfate, nitrate, fluoride, and deuterium had significantly greater concentrations in sites located in unconsolidated sediments than in consolidated rock; turbidity had the opposite pattern (Kruskal-Wallis test, $p \leq 0.05$).

INTRODUCTION

Purpose and Scope

The Upper Hassayampa groundwater basin (UHA) comprises approximately 787 square miles within Maricopa and Yavapai counties (Map 1).[4] The basin is located about 60 miles northwest of Phoenix and includes the Town of Wickenburg and the communities of Congress, Groom Creek, and Wagoner. The basin is drained by the Hassayampa River which heads in the Bradshaw Mountains in the extreme northern part of the basin and flows south until exiting the basin about five miles south of Wickenburg. There are no surface water diversions or impoundments besides stock ponds within the basin as groundwater is used for all municipal, domestic, irrigation, and industrial uses.[4]

Sampling by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring program is authorized by legislative mandate in the Arizona Revised Statutes §49-225, specifically: "*...ongoing monitoring of waters of the state, including...aquifers to detect the presence of new and existing pollutants, determine compliance with applicable water quality standards, determine the effectiveness of best management practices, evaluate the effects of pollutants on public health or the environment, and determine water quality trends*." [2]

Benefits of ADEQ Study – This study, which utilizes scientific sampling techniques and quantitative analyses, is designed to provide the following benefits:

- A characterization of regional groundwater quality conditions in the Upper Hassayampa basin identifying water quality variations between groundwater originating from different sources.

- A process for evaluating potential groundwater quality impacts arising from mineralization, mining, livestock, septic tanks, and poor well construction.

- A guide for determining areas where further groundwater quality research is needed.

Physical and Cultural Characteristics

Geography – The Upper Hassayampa basin is located within the Central highlands physiographic province of central Arizona and contains relatively small basins with alluvial deposits. The basin is characterized by mid-elevation mountains and valleys. Vegetation is composed of Arizona upland Sonoran and Mohave desert scrub, semi-desert grassland, interior chaparral, and limited montane conifer forest. Riparian vegetation includes mesquite, cottonwood, and willow found along perennial stretches of the Hassayampa River. [4]

The basin is bounded on the north by the Weaver Mountains, on the northwest by the Date Creek Mountains, on the south by the Vulture Mountains, and on the east by the Bradshaw Mountains. Elevations in the basin range from a high of approximately 7,000 feet above mean sea level (amsl) in the Bradshaw Mountains to a low of approximately 1,900 feet amsl at the railroad siding of Allah where the Hassayampa River exits the basin into the Phoenix Active Management Area.

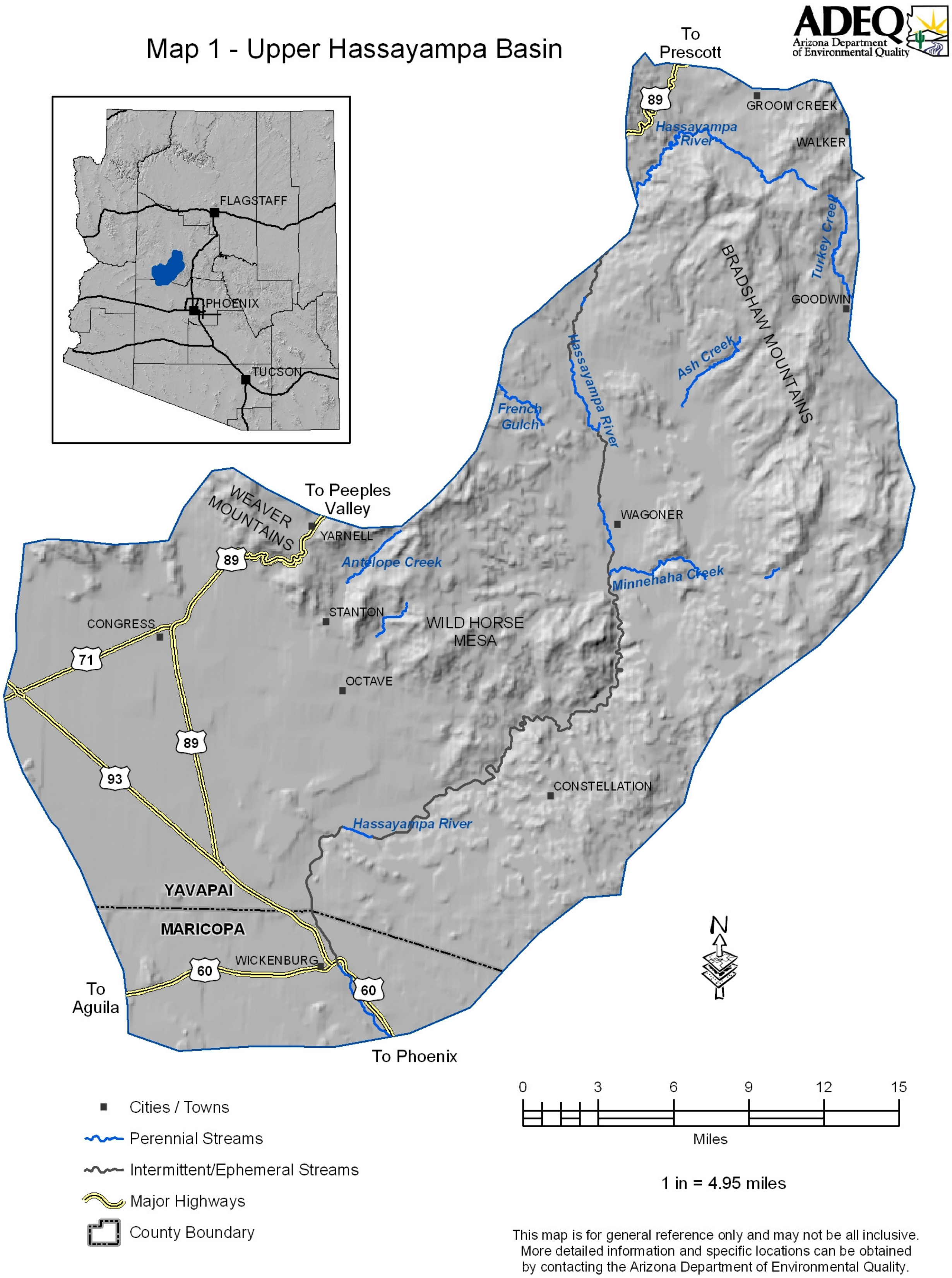
The Upper Hassayampa basin consists of federal land (46 percent) managed by the U.S. Forest Service (USFS) (25 percent) Bureau of Land Management (BLM) (21 percent). The remainder of the basin is composed of State Trust land (38 percent) and private land (16 percent).[3] Generally, USFS lands are located in the northeast portion, BLM lands are in the central portion, and State Trust and private land is interspersed throughout the southern two-thirds of the basin (Map 2).

Climate – The Upper Hassayampa basin is in an arid climate characterized by hot, dry summers and mild winters. There is wide variation in precipitation amounts which range annually from 10 inches in the southern portion near Wickenburg to 32 inches in the highest elevations of the Bradshaw Mountains. Precipitation occurs predominantly as rain in either late summer, localized thunderstorms or, less often, as widespread, low intensity winter rain that includes snow at higher elevations. [4]

Surface Water Characteristics

The basin is drained by the Hassayampa River, a tributary to the Gila River, which flows from north to south in the basin. The river is intermittent but has perennial flow in its upper reach and also in the extreme lower reach where groundwater is brought to the surface by bedrock south of Wickenburg. The Hassayampa River has a mean annual flow of 17,585 acre-feet at Box Dam site near Wickenburg. Perennial flow is also found in the upper reaches of Antelope Creek, Ash Creek, Weaver Creek, and Minnehaha Creek. Average seasonal flow is usually highest in the winter and lowest in the fall. [4]

Map 1 - Upper Hassayampa Basin



Groundwater Characteristics

Groundwater occurs primarily in the basin-fill aquifer, which is generally found in the southeast portion of the basin. The basin-fill aquifer is composed of gravel, sand, silt, and clay and may yield several hundred gallons per minute. In the main alluvial basin north of the Vulture Mountains, the basin-fill ranges from 25 feet thick to over 1,000 feet thick toward the center of the deposits. [4]

In the northern portion of the basin, smaller alluvial deposits may also be found in valleys. In some areas along the Hassayampa River, the crystalline rock is overlain by a thin cover of stream deposits that are up to 135 feet thick. Groundwater is also found in limited amounts in the consolidated crystalline and sedimentary rocks that make up the majority of the basin. [19]

Groundwater flows generally from north to south. Depth to groundwater varies significantly across the basin from just a few feet below land surface (bls) along some stretches of the Hassayampa River to over 1,000 feet bls in the center of the basin. Natural recharge estimates for the basin is 8,000 acre-feet per year while groundwater use is estimated to be 3,900 af/yr. Total estimated recoverable groundwater in storage in the basin-fill sediments to a depth of 1,200 feet bls is estimated around 1.0 million acre-feet (af). [4,19]

INVESTIGATION METHODS

ADEQ collected samples from 34 sites to characterize regional groundwater quality in the Upper Hassayampa basin (Map 2). Specifically, the following types of samples were collected:

- oxygen and deuterium isotopes at 34 sites
- inorganic suites at 34 sites
- radon at 17 sites
- radionuclides at 12 sites

In addition, four surface water isotope samples were collected; three from Hassayampa River and one from Minnehaha Creek. No bacteria sampling was conducted because microbiological contamination problems in groundwater are often transient and subject to a variety of changing environmental conditions including soil moisture content and temperature. [10]

Wells pumping groundwater for domestic, stock, irrigation, and monitoring purposes were sampled for the study, provided each well met ADEQ requirements. A well was considered suitable for sampling when the following conditions were met: the owner has given permission to sample, a sampling point existed near the wellhead, and the well casing and surface seal appeared to be intact and undamaged.[1, 5]

For this study, ADEQ personnel sampled 20 wells served by submersible pumps, 6 windmills, and 1 monitoring well. The wells were primarily used for domestic and/or stock use. Seven springs were also sampled that were primarily used for stock watering.

Additional information on groundwater sample sites is compiled from the Arizona Department of Water Resources (ADWR) well registry in Appendix A. [4]

Sample Collection

The sample collection methods for this study conformed to the *Quality Assurance Project Plan* (QAPP)[1] and the *Field Manual for Water Quality Sampling*.[5] While these sources should be consulted as references to specific sampling questions, a brief synopsis of the procedures involved in collecting a groundwater sample is provided.

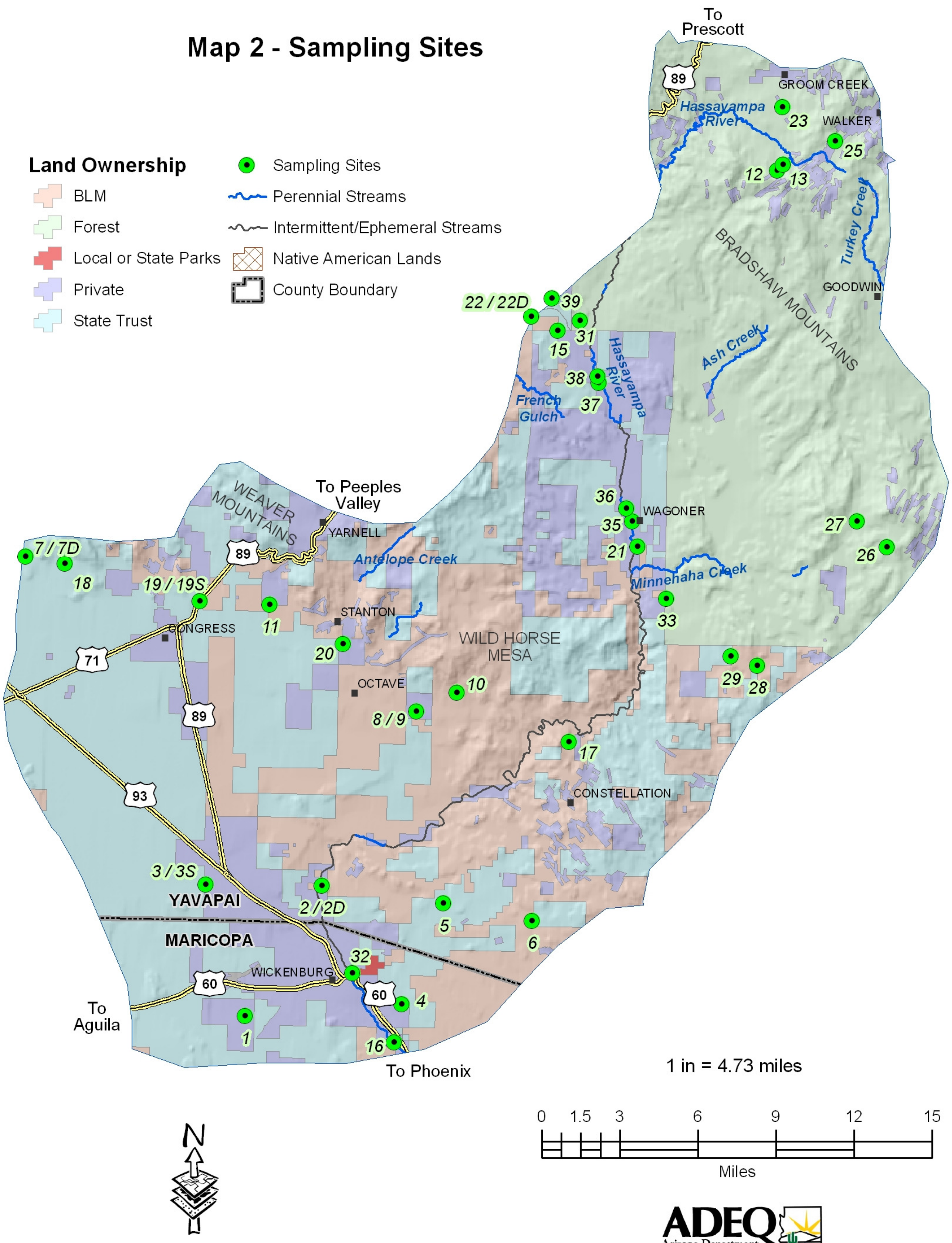
After obtaining permission from the well owner, the volume of water needed to purge the well three bore-hole volumes was calculated from well log and on-site information. Physical parameters—temperature, pH, and specific conductivity—were monitored at least every five minutes using a YSI multi-parameter instrument.

To assure obtaining fresh water from the aquifer, after three bore volumes had been pumped and physical parameter measurements had stabilized within 10 percent, a sample representative of the aquifer was collected from a point as close to the wellhead as possible. In certain instances, it was not possible to purge three bore volumes. In these cases, at least one bore volume was evacuated and the physical parameters had stabilized within 10 percent.

Sample bottles were filled in the following order:

1. Radon
2. Inorganics
3. Radionuclide
4. Isotopes

Radon, a naturally occurring, intermediate breakdown from the radioactive decay of uranium-238 to lead-206, was collected in two unpreserved, 40 milliliter (ml) clear glass vials. Radon samples were filled to minimize volatilization and sealed so that no headspace remained.[5, 20]



Map 2 - Sampling Sites
Land Ownership
BLM
Forest
Local or State Parks
Private
State Trust
Sampling Sites
Perennial Streams
Intermittent/Ephemeral Streams
Native American Lands
County Boundary
To Prescott
GROOM CREEK
WALKER
GOODWIN
Hassayampa River
Turkey Creek
BRADSHAW MOUNTAINS
Ash Creek
French Gulch
WEAVER MOUNTAINS
To Peeples Valley
YARNELL
Antelope Creek
WAGONER
Minnehaha Creek
STANTON
CONGRESS
WILD HORSE MESA
OCTAVE
CONSTELLATION
YAVAPAI
MARICOPA
WICKENBURG
To Aguila
To Phoenix
1 in = 4.73 miles
0 1.5 3 6 9 12 15
Miles
N

Figure 1 – The Diamond Two Ranch house well used for domestic purposes was sampled (UHA-35) for the ADEQ study. Analytical results indicated the water met all drinking water quality standards.

Figure 2 – Sinoski Spring used for livestock and wildlife purposes was sampled (UHA-10) for the ADEQ study. Analytical results indicated the water met all drinking water quality standards.

Figure 3 – Intermittent flow in the Hassayampa River at the Wagoner Road Bridge; the stream is perennial at higher and lower elevations in the basin.

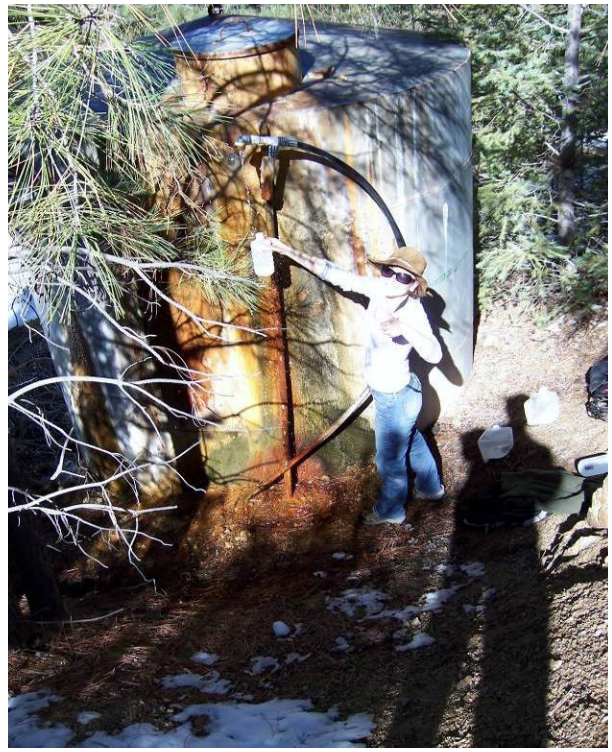


Figure 5 – ADEQ's Meghan Smart collects a sample (UHA-26) from Senator Spring located high in the Bradshaw Mountains along the road to Crown King.

Figure 4 – ADEQ's Douglas Towne stretches to collect a sample (UHA-28) from the Upper Oak Creek windmill. The water, which is used for livestock and wildlife, met all Primary and Secondary standards.

Figure 6 – ADEQ's Elizabeth Boettcher collects a sample (UHA-31) from Collins Spring located in the Prescott National Forest. Analytical results indicated the Secondary MCL for manganese was exceeded.

Figure 7 – An unused aqueduct, the Leppe Wash flume, is located on the historic TK Bar Ranch along the Hassayampa River near Kirkland, Arizona.

Figure 8 – ADEQ's Douglas Towne samples the well that serves Parker Dairy Farm located northwest of the town of Congress. Analytical results from the sample (UHA-11) indicated water from the 1,050-foot well exceeded water quality standards for TDS, nitrate, and gross alpha.

Figure 9 – Greg Norris, John Rebb, his wife, Sandy, and ADEQ's Elizabeth Boettcher pose for a photo after collecting samples (UHA-12 and UHA-13) from two wells near the top of the Upper Hassayampa basin by Groom Creek. Analytical results from both samples met all water quality standards.

Figure 10 – The 300-foot TK Bar Ranch Well #1 is shown pumping into a river-rock lined ditch. Nearby is the 500-foot TK Bar Ranch Well #2 that has artesian flow. Samples (UHA-37 and UHA-38) from both wells met all water quality standards.

The inorganic constituents were collected in three, one-liter polyethylene bottles: samples to be analyzed for dissolved metals were delivered to the laboratory unfiltered and unpreserved where they were subsequently filtered into bottles using a positive pressure filtering apparatus with a 0.45 micron (µm) pore size groundwater capsule filter and preserved with 5 ml nitric acid (70 percent). Samples to be analyzed for nutrients were preserved with 2 ml sulfuric acid (95.5 percent). Samples to be analyzed for other parameters were unpreserved.[5, 17, 20]

Radiochemistry samples were collected in two collapsible four-liter plastic containers and preserved with 5 ml nitric acid to reduce the pH below 2.5 su.[5] Oxygen and hydrogen isotope samples were collected in a 250 ml polyethylene bottle with no preservative.[5, 24]

All samples were kept at 4°C with ice in an insulated cooler, with the exception of the oxygen and hydrogen isotope samples.[5,17,20] Chain of custody procedures were followed in sample handling. Samples for this study were collected during eight field trips conducted between 2003 and 2009.

Laboratory Methods

The inorganic analyses for all inorganic samples, except two split samples, were conducted by the Arizona Department of Health Services (ADHS) Laboratory in Phoenix, Arizona. The inorganic analyses for the two split samples (UHA-3s and UHA-19s) were conducted by Test America Laboratory in Phoenix, Arizona. A complete listing of inorganic parameters, including laboratory method and Minimum Reporting Level (MRL) for each laboratory is provided in Table 1.

Radon samples were submitted to Test America Laboratory and analyzed by Radiation Safety Engineering, Inc. Laboratory in Chandler, Arizona. Isotope samples were analyzed by the Department of Geosciences, Laboratory of Isotope Geochemistry at the University of Arizona in Tucson, Arizona.

DATA EVALUATION

Quality Assurance

Quality-assurance (QA) procedures were followed and quality-control (QC) samples were collected to quantify data bias and variability for the Upper Hassayampa basin study. The design of the QA/QC plan was based on recommendations included in the *Quality Assurance Project Plan* (*QAPP*) and *the Field Manual For Water Quality Sampling*.[1, 5] Types and numbers of QC samples collected for this study include three duplicates, one partial duplicate, two splits, and two equipment blanks for inorganic samples.

Based on the QA/QC results, sampling procedures and laboratory equipment did not significantly affect the groundwater quality samples.

Blanks – Three equipment blanks for inorganic analyses were collected and delivered to the ADHS laboratory to ensure adequate decontamination of sampling equipment, and that the filter apparatus and/or de-ionized water were not impacting the groundwater quality sampling.[5] Equipment blank samples for major ion and nutrient analyses were collected by filling unpreserved and sulfuric acid preserved bottles with de-ionized water. Equipment blank samples for trace element analysis were collected with de-ionized water that had been filtered into nitric acid preserved bottles.

Systematic contamination was judged to occur if more than 50 percent of the equipment blank samples contained measurable quantities of a particular groundwater quality constituent. The equipment blanks contained turbidity and specific conductivity (SC-lab) at expected levels due to impurities in the source water used for the samples. Phosphorus was also detected in one sample.

For turbidity, the three blanks had a mean level of 0.04 nephelometric turbidity units (ntu) less than 1 percent of the turbidity mean level for the study and were not considered to be significantly affecting the sample results. Testing indicates turbidity is present at 0.01 ntu in the de-ionized water supplied by the ADHS laboratory, and levels increase with time due to storage in ADEQ carboys.[17]

For SC, two equipment blanks had a mean value of 2.65 micro-siemens per cm (uS/cm) which was less than 1 percent of the SC mean concentration for the study and was not considered to be significantly affecting the sample results. The SC detections may have occurred when water passing through a de-ionizing exchange unit normally has an SC value of at least 1 uS/cm. Carbon dioxide from the air can also dissolve in de-ionized water with the resulting bicarbonate and hydrogen ions imparting the observed conductivity.[17]

For total phosphorus, one blank had a concentration of 0.03 mg/L that is less than 1 percent of the total phosphorus mean level for the study.

Table 1. Laboratory Water Methods and Minimum Reporting Levels Used in the Study

Constituent	Instrumentation	ADHS / Test America Water Method	ADHS / Test America Minimum Reporting Level
Physical Parameters and General Mineral Characteristics			
Alkalinity	Electrometric Titration	SM 2320B / M 2320 B	2 / 6
SC (µS/cm)	Electrometric	EPA 120.1/ M 2510 B	-- / 2
Hardness	Titrimetric, EDTA	SM 2340 C / SM 2340B	10 / 1
Hardness	Calculation	SM 2340 B	--
pH (su)	Electrometric	SM 4500 H-B	0.1
TDS	Gravimetric	SM 2540C	10
Turbidity (NTU)	Nephelometric	EPA 180.1	0.01 / 0.2
Major Ions			
Calcium	ICP-AES	EPA 200.7	1 / 2
Magnesium	ICP-AES	EPA 200.7	1 / 0.25
Sodium	ICP-AES	EPA 200.7	1 / 2
Potassium	Flame AA	EPA 200.7	0.5 / 2
Bicarbonate	Calculation	Calculation / M 2320 B	2
Carbonate	Calculation	Calculation / M 2320 B	2
Chloride	Potentiometric Titration	SM 4500 CL D / E 300	5 / 2
Sulfate	Colorimetric	EPA 375.4 / E 300	1 / 2
Nutrients			
Nitrate as N	Colorimetric	EPA 353.2	0.02 / 0.1
Nitrite as N	Colorimetric	EPA 353.2	0.02 / 0.1
Ammonia	Colorimetric	EPA 350.1/ EPA 350.3	0.02 / 0.5
TKN	Colorimetric	EPA 351.2 / M 4500-NH3	0.05 / 1.3
Total Phosphorus	Colorimetric	EPA 365.4 / M 4500-PB	0.02 / 0.1

All units are mg/L except as noted
Source [17, 20]

Table 1. Laboratory Water Methods and Minimum Reporting Levels Used in the Study-Continued

Constituent	Instrumentation	ADHS / Test America Water Method	ADHS / Test America Minimum Reporting Level
Trace Elements			
Aluminum	ICP-AES	EPA 200.7	0.5 / 0.2
Antimony	Graphite Furnace AA	EPA 200.8	0.005 / 0.003
Arsenic	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.005 / 0.001
Barium	ICP-AES	EPA 200.8 / EPA 200.7	0.005 to 0.1 / 0.01
Beryllium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.0005 / 0.001
Boron	ICP-AES	EPA 200.7	0.1 / 0.2
Cadmium	Graphite Furnace AA	EPA 200.8	0.0005 / 0.001
Chromium	Graphite Furnace AA	EPA 200.8 / EPA 200.7	0.01 / 0.01
Copper	Graphite Furnace AA	EPA 200.8 / EPA 200.7	0.01 / 0.01
Fluoride	Ion Selective Electrode	SM 4500 F-C	0.1 / 0.4
Iron	ICP-AES	EPA 200.7	0.1 / 0.05
Lead	Graphite Furnace AA	EPA 200.8	0.005 / 0.001
Manganese	ICP-AES	EPA 200.7	0.05 / 0.01
Mercury	Cold Vapor AA	SM 3112 B / EPA 245.1	0.0002
Nickel	ICP-AES	EPA 200.7	0.1 / 0.01
Selenium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.005 / 0.002
Silver	Graphite Furnace AA	EPA 200.9 / EPA 200.7	0.001 / 0.01
Strontium	ICP-AES	EPA 200.7	0.1 / 0.1
Thallium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.002 / 0.001
Zinc	ICP-AES	EPA 200.7	0.05
Radionuclides			
Radon	Liquid scintillation counter	EPA 913.1	varies

All units are mg/L Source [17, 20]

Duplicate Samples – Duplicate samples are identical sets of samples collected from the same source at the same time and submitted to the same laboratory. Data from duplicate samples provide a measure of variability from the combined effects of field and laboratory procedures.[5] Duplicate samples were collected from sampling sites that were believed to have elevated or unique constituent concentrations as judged by SC-field and pH-field values.

Three duplicate samples and one partial duplicate sample were collected and submitted to the ADHS laboratory for this study. Analytical results indicate that of the 40 constituents examined, 20 had concentrations above the MRL. The duplicate samples had an excellent correlation as the maximum variation between constituents was less than 5 percent except for total phosphorus (9 percent), TKN (10 percent), and turbidity (32 percent) (Table 2).

Split Samples – Split samples are identical sets of samples collected from the same source at the same time that are submitted to two different laboratories to check for laboratory differences.[5] Three inorganic split samples were collected and distributed between the ADHS and Test America labs. The analytical results were evaluated by examining the variability in constituent concentrations in terms of absolute levels and as the percent difference.

Analytical results indicate that of the 36 constituents examined, 20 had concentrations above MRLs for both ADHS and Test America laboratories (Table 3). The maximum variation between constituents was below 5 percent except for zinc (10 percent), chloride (15 percent), potassium (21 percent), turbidity (28 percent), copper (90 percent), and TKN (95 percent).

Split samples were also evaluated using the non-parametric Sign test to determine if there were any significant differences between ADHS laboratory and Test America laboratory analytical results.[27] There were no significant differences in constituent concentrations between the labs (Sign test, $p \leq 0.05$).

Based on the results of blank, duplicate, and split samples collected for this study, no significant QA/QC problems were apparent with the study.

Data Validation

The analytical work for this study was subjected to four QA/QC correlations and considered valid based on the following results. [13]

Cation/Anion Balances – In theory, water samples exhibit electrical neutrality. Therefore, the sum of milliequivalents per liter (meq/L) of cations should equal the sum of meq/L of anions. However, this neutrality rarely occurs due to unavoidable variation inherent in all water quality analyses. Still, if the cation/anion balance is found to be within acceptable limits, it can be assumed there are no gross errors in concentrations reported for major ions.[13]

Overall, cation/anion meq/L balances of Upper Hassayampa basin samples were significantly correlated (regression analysis, $p \leq 0.01$). Of the 34 samples, all were within +/-5 percent. Nineteen samples had low cation/high anion sums; 15 samples had high cation/low anion sums.

SC/TDS –- The SC and TDS concentrations measured by contract laboratories were significantly correlated as were SC-field and TDS concentrations (regression analysis, $r = 0.98$, $p \leq 0.01$). The TDS concentration in mg/L should be from 0.55 to 0.75 times the SC in µS/cm for groundwater up to several thousand TDS mg/L.[13]

Groundwater high in bicarbonate and chloride will have a multiplication factor near the lower end of this range; groundwater high in sulfate may reach or even exceed the higher factor. The relationship of TDS to SC becomes undefined with very high or low concentrations of dissolved solids.[13]

SC –- The SC measured in the field at the time of sampling was significantly correlated with the SC measured by contract laboratories (regression analysis, $r = 0.99$, $p \leq 0.01$).

Hardness – Concentrations of laboratory-measured and calculated values of hardness were significantly correlated (regression analysis, $r = 0.99$, $p \leq 0.01$). Hardness concentrations were calculated using the following formula: [(calcium x 2.497) + (magnesium x 4.118)]. [13]

pH – The pH value is closely related to the environment of the water and is likely to be altered by sampling and storage.[13] The pH values measured in the field using a YSI meter at the time of sampling were not significantly correlated with laboratory pH values (regression analysis, $r = 0.36$, $p \geq 0.05$).

Table 2. Summary Results of Duplicate Samples from ADHS Laboratory

Parameter	Number of Dup. Samples	Difference in Percent			Difference in Concentrations		
		Minimum	Maximum	Median	Minimum	Maximum	Median
Physical Parameters and General Mineral Characteristics							
Alk., Total	3	0 %	2 %	0 %	0	10	6
SC (µS/cm)	3	0 %	1 %	0 %	0	10	6
Hardness	3	0 %	3 %	2 %	0	20	10
pH (su)	3	0 %	1 %	3 %	0	0.4	0.1
TDS	3	0 %	2 %	1 %	0	10	10
Turb. (ntu)	3	4 %	32 %	7 %	0.01	1	0.49
Major Ions							
Calcium	4	0 %	3 %	2 %	0.3	4	3
Magnesium	4	0 %	3 %	2 %	0	1	1
Sodium	4	0 %	1 %	0 %	0	2	1
Potassium	4	0 %	2 %	0 %	0	0.1	0
Bicarbonate	3	0 %	2 %	0 %	0	10	0
Chloride	3	0 %	0 %	0 %	0	0	0
Sulfate	3	0 %	0 %	0 %	0	0	0
Nutrients							
Nitrate (as N)	3	0 %	5 %	2 %	0	0.1	0.1
Phosphorus, T.	3	0 %	9 %	1 %	0	0.005	0.001
TKN *	1	-	-	10 %	-	-	0.03
Trace Elements							
Barium	1	-	-	0 %	-	-	0
Boron	2	0 %	5 %	-	0	0.1	-
Fluoride	3	0 %	2 %	0 %	0	0.1	0
Zinc**	1	-	-	1 %	-	-	0.1

All concentration units are mg/L except as noted with certain physical parameters.
* = TKN was detected in one sample (UHA-2) at a concentration of 0.082 mg/L and not detected in the duplicate (UHA-2D)
** = Zinc was detected in one sample (UHA-22) at a concentration of 0.41 mg/L and not detected in the duplicate (UHA-22D)
Copper was detected in two samples (UHA-7 and UHA-8) and not detected in the duplicate samples (UHA-7D and UHA-9)
Nickel was detected in one sample (UHA-8) at a concentration of 0.12 mg/L and not detected in the duplicate samples (UHA-9)

Table 3. Summary Results of Split Samples between ADHS / Test America Labs

Constituents	Number of Split Sites	Difference in Percent		Difference in Levels		Significance
		Minimum	Maximum	Minimum	Maximum	
Physical Parameters and General Mineral Characteristics						
Alkalinity, total	3	0 %	3 %	0	12	ns
SC (µS/cm)	3	0 %	2 %	0	20	ns
Hardness	2	1 %	4 %	8	10	ns
pH (su)	3	0 %	3 %	0.1	0.38	ns
TDS	3	0 %	5 %	0	100	ns
Turbidity (ntu)	1	28 %	28 %	1.5	1.5	ns
Major Ions						
Calcium	3	2 %	5 %	2	10	ns
Magnesium	3	1 %	4 %	1	1	ns
Sodium	3	0 %	3 %	0	2	ns
Potassium	3	11 %	21 %	1.5	1.9	ns
Chloride	3	0 %	15 %	0	9	ns
Sulfate	3	0 %	9 %	0	9	ns
Nutrients						
Nitrate as N	1	4 %	4 %	0.08	0.08	ns
TKN*	1	95 %	95 %	16.6	16.6	ns
Trace Elements						
Barium	1	4 %	4 %	0.008	0.008	ns
Chromium	1	0 %	0 %	0	0	ns
Copper	1	90 %	90 %	0.1139	0.1139	ns
Fluoride	3	0 %	4 %	0	0.03	ns
Zinc	2	0 %	10 %	0	0.03	ns

ns = No significant (p □ ≤ 0.05) difference
All units are mg/L except as noted
* = TKN was detected by Test America in (UHA-3S) at 1.1 mg/L and not detected in the ADHS split sample (UHA-3)
Ammonia was detected by Test America in (UHA-19S) at 0.68 mg/L and not detected in the ADHS split sample (UHA-19)
Total phosphorus was detected by ADHS in (UHA-16) at 0.074 mg/L and not detected in the Test Am. split sample (UHA-17a)
Nickel was detected by ADHS in (UHA-16) at 0.25 mg/L and not detected in the Test America split sample (UHA-17a)
Zinc was detected by Test America in (UHA-17a) at 0.076 mg/L and not detected in the ADHS split sample (UHA-16)

Statistical Considerations

Various statistical analyses were used to examine the groundwater quality data of the study. All statistical tests were conducted using SYSTAT software.[27]

Data Normality: Data associated with 22 constituents were tested for non-transformed normality using the Kolmogorov-Smirnov one-sample test with the Lilliefors option.[6]

Results of this test revealed that 17 of the 22 constituents examined were not normally distributed. Only five constituents were normally distributed: temperature, pH-field, bicarbonate, total alkalinity, and oxygen.

Spatial Relationships: The non-parametric Kruskal-Wallis test using untransformed data was applied to investigate the hypothesis that constituent concentrations from groundwater sites having different aquifers were the same.

The Kruskal-Wallis test uses the differences, but also incorporates information about the magnitude of each difference.[27] The null hypothesis of identical mean values for all data sets within each test was rejected if the probability of obtaining identical means by chance was less than or equal to 0.05. The Kruskal-Wallis test is not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[12]

Correlation Between Constituents: In order to assess the strength of association between constituents, their concentrations were compared to each other using the non-parametric Kendall's tau-b test. Kendall's correlation coefficient varies between -1 and +1; with a value of +1 indicating that a variable can be predicted perfectly by a positive linear function of the other, and vice versa. A value of -1 indicates a perfect inverse or negative relationship.

The results of the Kendall's tau-b test were then subjected to a probability test to determine which of the individual pair wise correlations were significant.[27] The Kendall's tau-b test is not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[12]

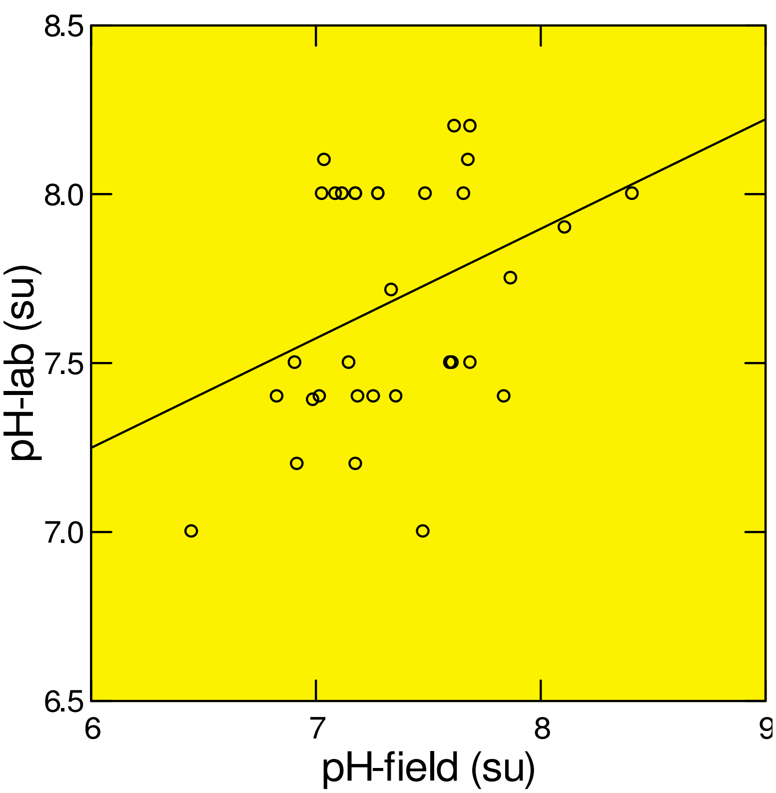


Diagram 1 – The 34 samples collected in the Upper Hassayampa basin are plotted according to their pH-field and pH-laboratory values. The graph shows the weak correlation between these two related parameters. The relationship is described by the regression equation: $y = 0.32x + 5.3$, $r = 0.36$. The pH value is closely related to the environment of the water and is likely to be altered by sampling and storage.[13]

GROUNDWATER SAMPLING RESULTS

Water Quality Standards/Guidelines

The ADEQ ambient groundwater program characterizes regional groundwater quality. An important determination ADEQ makes concerning the collected samples is how the analytical results compare to various drinking water quality standards.

ADEQ used three sets of drinking water standards that reflect the best current scientific and technical judgment available to evaluate the suitability of groundwater in the basin for drinking water use:

- Federal Safe Drinking Water (SDW) Primary Maximum Contaminant Levels (MCLs). These enforceable health-based standards establish the maximum concentration of a constituent allowed in water supplied by public systems.[25]

- State of Arizona Aquifer Water Quality Standards. These apply to aquifers that are classified for drinking water protected use. All aquifers within Arizona are currently classified and protected for drinking water use. These enforceable State standards are identical to the federal Primary MCLs except for arsenic which is at 0.05 mg/L compared with the federal Primary MCL of 0.01 mg/L.[2]

- Federal SDW Secondary MCLs. These non-enforceable aesthetics-based guidelines define the maximum concentration of a constituent that can be present without imparting unpleasant taste, color, odor, or other aesthetic effects on the water.[25]

Health-based drinking water quality standards (such as Primary MCLs) are based on the lifetime consumption (70 years) of two liters of water per day and, as such, are chronic not acute standards.[25] Exceedances of specific constituents for each groundwater site is found in Appendix B.

Overall Results – Of the 34 sites sampled in the Upper Hassayampa study, 20 sites met all health-based and aesthetics-based, water quality standards (excluding the proposed radon standard discussed below). Of the 34 sites sampled in the Upper Hassayampa study, health-based water quality standards were exceeded at 9 sites (27 percent). Constituents above Primary MCLs include arsenic (1 site), gross alpha (5 sites), and nitrate (4 sites).

Inorganic Constituent Results - Of the 34 sites sampled for the full suite of inorganic constituents (excluding radionuclide sample results) in the Upper Hassayampa study, 20 sites (59 percent) met all health-based and aesthetics-based, water quality standards. Health-based Primary MCL water quality standards and State aquifer water quality standards were exceeded at 5 sites (15 percent) of the 34 sites (Map 3; Table 4). Constituents above Primary MCLs include arsenic (1 site) and nitrate (4 sites). Potential impacts of these Primary MCL exceedances are given in Table 5. Aesthetics-based Secondary MCL water quality guidelines were exceeded at 13 of 34 sites (38 percent; Map 3; Table 5). Constituents above Secondary MCLs include chloride (1 site), fluoride (4 sites), iron (2 sites), manganese (4 sites), sulfate (1 site), TDS (8 sites). Potential impacts of these Secondary MCL exceedances are given in Table 5.

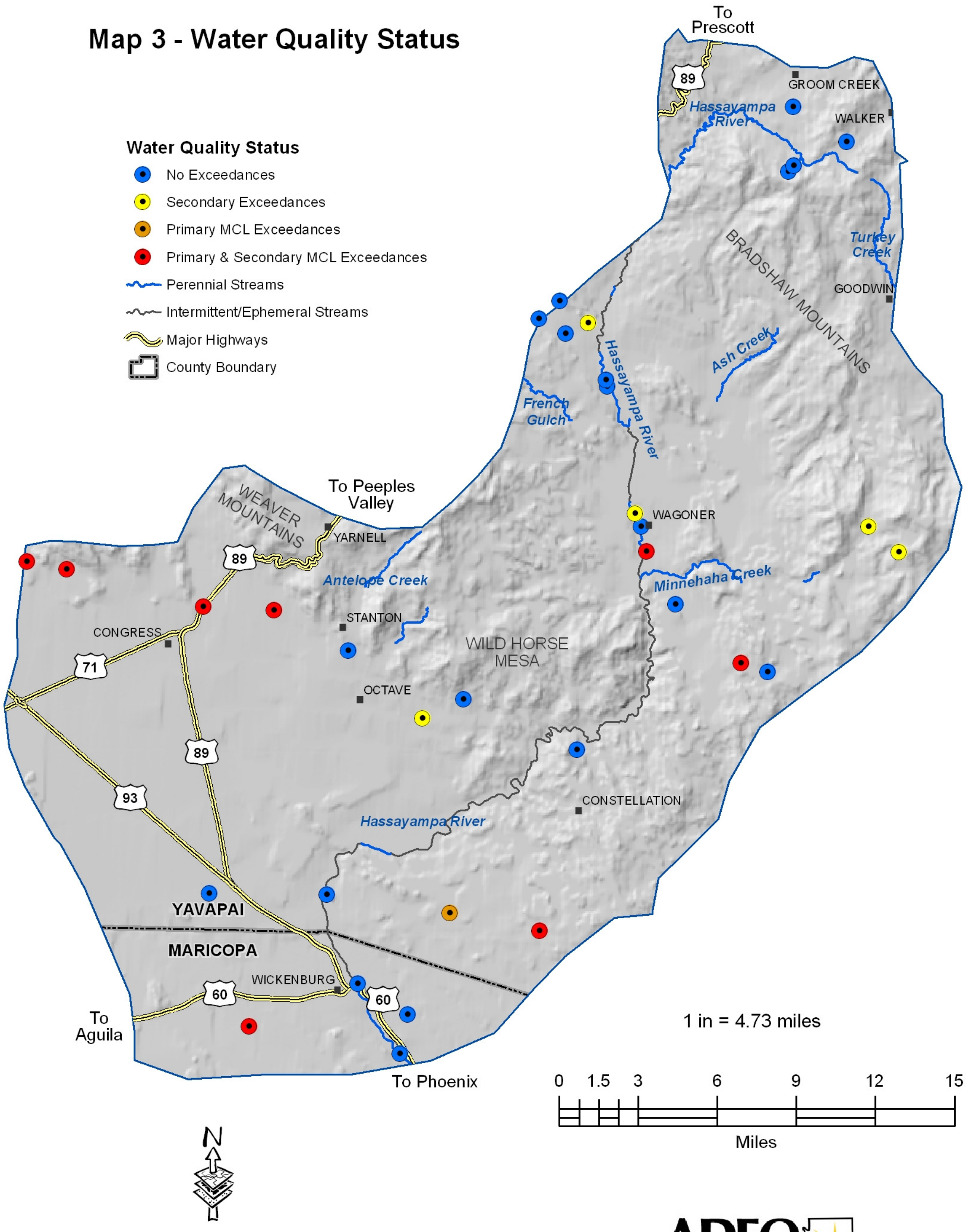
Radon Results - Of the 17 sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes an enhanced multimedia program to address the health risks from radon in indoor air. Eight sites exceeded the proposed 300 pCi/L standard (Table 4; Map 4) that would apply if Arizona doesn't develop a multimedia program.[25]

Suitability for Irrigation

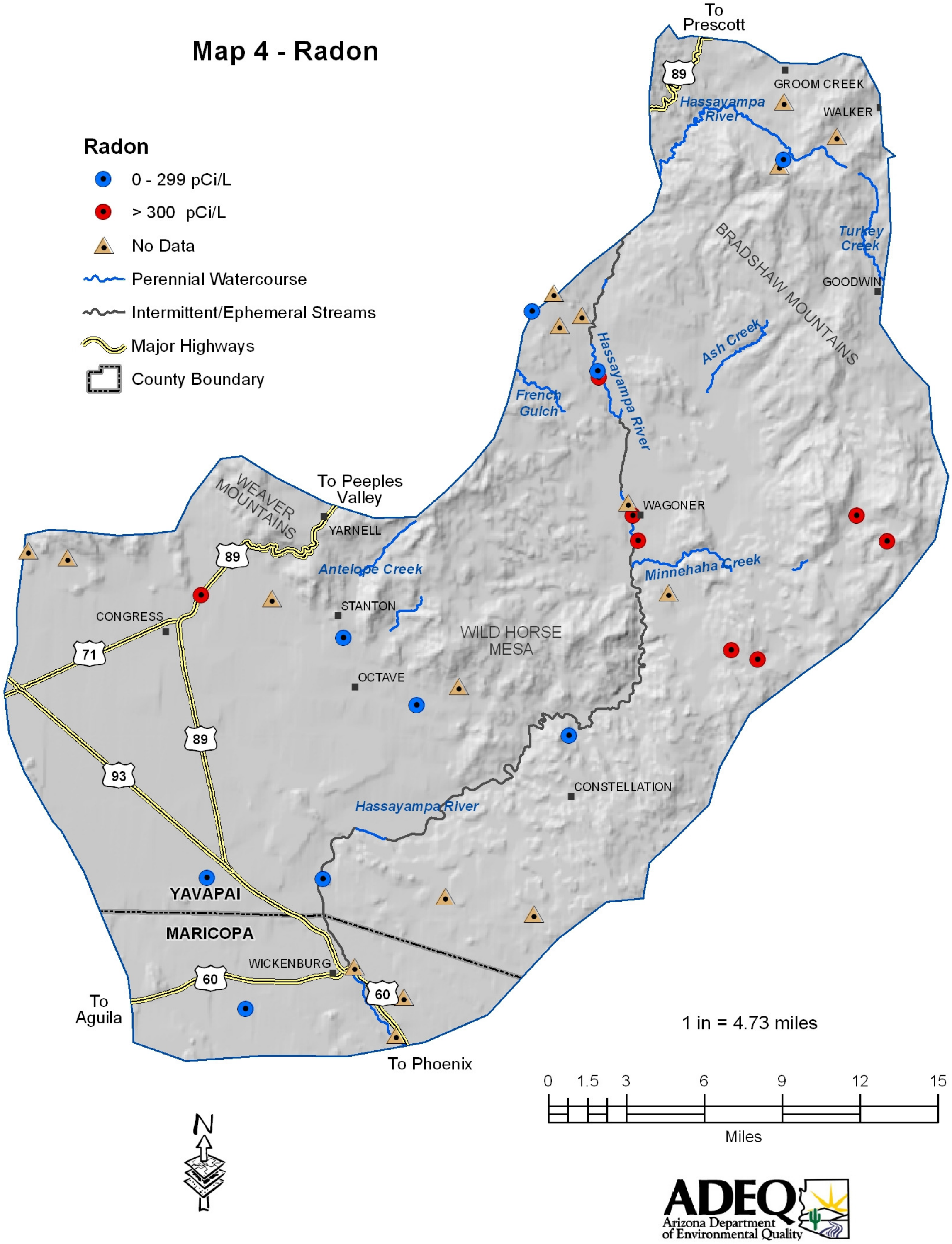
The groundwater at each sample site was assessed as to its suitability for irrigation use based on salinity and sodium hazards. Excessive levels of sodium are known to cause physical deterioration of the soil and vegetation. Irrigation water may be classified using SC and the Sodium Adsorption Ratio (SAR) in conjunction with one another.[26] Groundwater sites in the Upper Hassayampa basin display a narrow range of irrigation water classifications. Samples had a "low" sodium hazard and a "medium" or "high" salinity hazard (Table 6).

Analytical Results

Analytical inorganic and radiochemistry results of the Upper Hassayampa basin sample sites are summarized (Table 7) using the following indices: MRLs, number of sample sites over the MRL, upper and lower 95 percent confidence intervals ($CI_{95\%}$), median, and mean. Confidence intervals are a statistical tool which indicates that 95 percent of a constituent's population lies within the stated confidence interval.[27] Specific constituent information for each sampled groundwater site is in Appendix B.


Map 3 - Water Quality Status
Water Quality Status
No Exceedances
Secondary Exceedances
Primary MCL Exceedances
Primary & Secondary MCL Exceedances
Perennial Streams
Intermittent/Ephemeral Streams
Major Highways
County Boundary
To Prescott
89
GROOM CREEK
Hassayampa River
WALKER
Turkey Creek
BRADSHAW MOUNTAINS
GOODWIN
Ash Creek
Hassayampa River
French Gulch
To Peeples Valley
WEAVER MOUNTAINS
YARNELL
89
WAGONER
Antelope Creek
Minnehaha Creek
STANTON
CONGRESS
WILD HORSE MESA
71
OCTAVE
89
93
CONSTELLATION
Hassayampa River
YAVAPAI
MARICOPA
WICKENBURG
60
60
To Aguila
To Phoenix
1 in = 4.73 miles
0 1.5 3 6 9 12 15
Miles
N

Map 4 - Radon



Radon
0 - 299 pCi/L
> 300 pCi/L
No Data
Perennial Watercourse
Intermittent/Ephemeral Streams
Major Highways
County Boundary
To Prescott
89
GROOM CREEK
WALKER
Hassayampa River
Turkey Creek
GOODWIN
BRADSHAW MOUNTAINS
Ash Creek
French Gulch
Hassayampa River
WAGONER
Minnehaha Creek
WEAVER MOUNTAINS
To Peeples Valley
YARNELL
89
Antelope Creek
STANTON
CONGRESS
71
WILD HORSE MESA
OCTAVE
89
93
CONSTELLATION
Hassayampa River
YAVAPAI
MARICOPA
WICKENBURG
60
60
To Aguila
To Phoenix
1 in = 4.73 miles
0
1.5
3
6
9
12
15
Miles
N
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Table 4. Sampled Sites Exceeding Health-based Water Quality Standards or Primary MCLs

Constituent	Primary MCL	Number of Sites Exceeding Primary MCL	Highest Concentration	Potential Health Effects of MCL Exceedances *
		Nutrients		
Nitrite (NO_2-N)	1.0	0	-	-
Nitrate (NO_3-N)	10.0	**4**	19	methemoglobinemia
		Trace Elements		
Antimony (Sb)	0.006	0	-	-
Arsenic (As)	0.01	**1**	0.010	dermal and nervous system toxicity
Arsenic (As)	0.05	0	-	-
Barium (Ba)	2.0	0	-	-
Beryllium (Be)	0.004	0	-	-
Cadmium (Cd)	0.005	0	-	-
Chromium (Cr)	0.1	0	-	-
Copper (Cu)	1.3	0	-	-
Fluoride (F)	4.0	0	-	-
Lead (Pb)	0.015	0	-	-
Mercury (Hg)	0.002	0	-	-
Nickel (Ni)	0.1	0	-	-
Selenium (Se)	0.05	0	-	-
Thallium (Tl)	0.002	0	-	-
		Radiochemistry Constituents		
Gross Alpha	15	**5**	75	cancer
Ra-226+Ra-228	5	0	-	-
Radon **	300	**8**	2,641	cancer
Radon **	4,000	0	-	-
Uranium	30	0	-	-

All units are mg/L except gross alpha, radium-226+228 and radon (pCi/L), and uranium (ug/L).
* Health-based drinking water quality standards are based on a lifetime consumption of two liters of water per day over a 70-year life span.[25]
** Proposed EPA Safe Drinking Water Act standards for radon in drinking water.[25]

Table 5. Sampled Sites Exceeding Aesthetics-Based (Secondary MCL) Water Quality Standards

Constituents	Secondary MCL	Number of Sites Exceeding Secondary MCLs	Concentration Range of Exceedances	Aesthetic Effects of MCL Exceedances
Physical Parameters				
pH - field	< 6.5	0	-	-
pH - field	> 8.5	0	-	-
General Mineral Characteristics				
TDS	500	**8**	2,300	hardness; deposits; colored water; staining; salty taste
Major Ions				
Chloride (Cl)	250	**1**	420	salty taste
Sulfate (SO_4)	250	**1**	1,100	salty taste
Trace Elements				
Fluoride (F)	2.0	**4**	3.5	tooth discoloration
Iron (Fe)	0.3	**2**	0.95	rusty color; sediment; metallic taste; reddish or orange staining
Manganese (Mn)	0.05	**4**	1.5	black staining; bitter metallic taste
Silver (Ag)	0.1	0	**-**	**-**
Zinc (Zn)	5.0	0	**-**	**-**

All units mg/L except pH is in standard units (su). Source: [25]

Table 6. Sodium and Salinity Hazards for Sampled Sites

Hazard	Total Sites	Low	Medium	High	Very High
Sodium Hazard					
Sodium Adsorption Ratio (SAR)		0 - 10	10- 18	18 - 26	> 26
Sample Sites	34	34	0	0	0
Salinity Hazard					
Specific Conductivity (µS/cm)		100–250	250 – 750	750-2250	>2250
Sample Sites	34	1	21	10	2

Table 7. Summary Statistics for Groundwater Quality Data

Constituent	Minimum Reporting Limit (MRL)*	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
Physical Parameters						
Temperature (^{o}C)	0.1	34 / 32	20.2	18.1	20.0	22.0
pH-field (su)	0.01	34 / 33	7.28	7.21	7.35	7.49
pH-lab (su)	0.01	34 / 34	7.66	7.56	7.68	7.81
Turbidity (ntu)	0.01 / 0.20	34 / 34	1.1	0.5	7.5	14.4
General Mineral Characteristics						
T. Alkalinity	2.0 / 6.0	34 / 34	260	235	264	294
Phenol. Alk.	2.0 / 6.0	34 / 0	> 50% of data below MRL			
SC-field (µS/cm)	N/A	34 / 34	717	616	784	952
SC-lab (µS/cm)	N/A / 2.0	34 / 34	665	593	769	945
Hardness-lab	10 / 6	34 / 34	260	232	306	379
TDS	10 / 20	34 / 34	410	349	482	615
Major Ions						
Calcium	5 / 2	34 / 34	78	65	85	105
Magnesium	1.0 / 0.25	34 / 34	20	18	24	30
Sodium	5 / 2	34 / 34	34	31	45	59
Potassium	0.5 / 2.0	34 / 33	2.1	1.9	2.6	3.2
Bicarbonate	2.0 / 6.0	34 / 34	320	285	321	357
Carbonate	2.0 / 6.0	34 / 0	> 50% of data below MRL			
Chloride	1 / 20	34 / 33	26	20	45	70
Sulfate	10 / 20	34 / 33	34	9	73	138
Nutrients						
Nitrate (as N)	0.02 / 0.20	34 / 28	1.3	1.3	2.8	4.3
Nitrite (as N)	0.02 / 0.20	34 / 1	> 50% of data below MRL			
TKN	0.05 / 1.0	34 / 18	> 50% of data below MRL			
Ammonia	0.02 / 0.05	34 / 1	> 50% of data below MRL			
T. Phosphorus	0.02 / 0.10	34 / 15	> 50% of data below MRL			

Table 7. Summary Statistics for Groundwater Quality Data—Continued

Constituent	Minimum Reporting Limit (MRL)*	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
			Trace Elements			
Aluminum	0.5 / 0.2	22 / 0		> 50% of data below MRL		
Antimony	0.005 / 0.003	34 / 0		> 50% of data below MRL		
Arsenic	0.01 / 0.001	34 / 3		> 50% of data below MRL		
Barium	0.1 / 0.001	34 / 14		> 50% of data below MRL		
Beryllium	0.0005 / 0.001	34 / 0		> 50% of data below MRL		
Boron	0.1 / 0.2	34 / 9		> 50% of data below MRL		
Cadmium	0.001	34 / 0		> 50% of data below MRL		
Chromium	0.01 / 0.001	34 / 3		> 50% of data below MRL		
Copper	0.01 / 0.001	34 / 4		> 50% of data below MRL		
Fluoride	0.2 / 0.4	34 / 34	0.5	0.5	0.8	1.1
Iron	0.1 / 0.05	34 / 4		> 50% of data below MRL		
Lead	0.005 / 0.001	34 / 0		> 50% of data below MRL		
Manganese	0.05 / 0.01	34 / 4		> 50% of data below MRL		
Mercury	0.0005 / 0.0002	34 / 0		> 50% of data below MRL		
Nickel	0.1 / 0.01	34 / 0		> 50% of data below MRL		
Selenium	0.005 / 0.002	34 / 0		>50% of data below MRL		
Silver	0.001	34 / 0		> 50% of data below MRL		
Thallium	0.002 / 0.001	34 / 0		> 50% of data below MRL		
Zinc	0.05	34 / 16		> 50% of data below MRL		
			Radiochemical			
Radon (pCi/L)	Varies	17 / 17	264	184	307	430
			Isotopes			
Oxygen-18 **	Varies	34 / 34	- 9.4	- 9.8	- 9.4	- 9.1
Deuterium **	Varies	34 / 34	- 66.0	- 68.9	- 67.2	- 65.6

* = ADHS MRL / Test America MRL　　All units mg/L except where noted or ** = 0/00

GROUNDWATER COMPOSITION

General Summary

The water chemistry at the 34 sample sites in the Upper Hassayampa basin (in decreasing frequency) include calcium-bicarbonate (18 sites), mixed-bicarbonate (12 sites), and calcium-chloride, calcium-mixed, mixed-sulfate, and mixed-mixed (1 site apiece) (Diagram 2 – middle figure) (Map 5).

Calcium was the dominant cation at 20 sites. At 14 sites the composition was mixed as there was no dominant cation (Diagram 2 – left figure).

The dominant anion was bicarbonate at 30 sites and chloride and sulfate at one site apiece. The composition was mixed as there was no dominant anion at two sites (Diagram 2 – right figure).

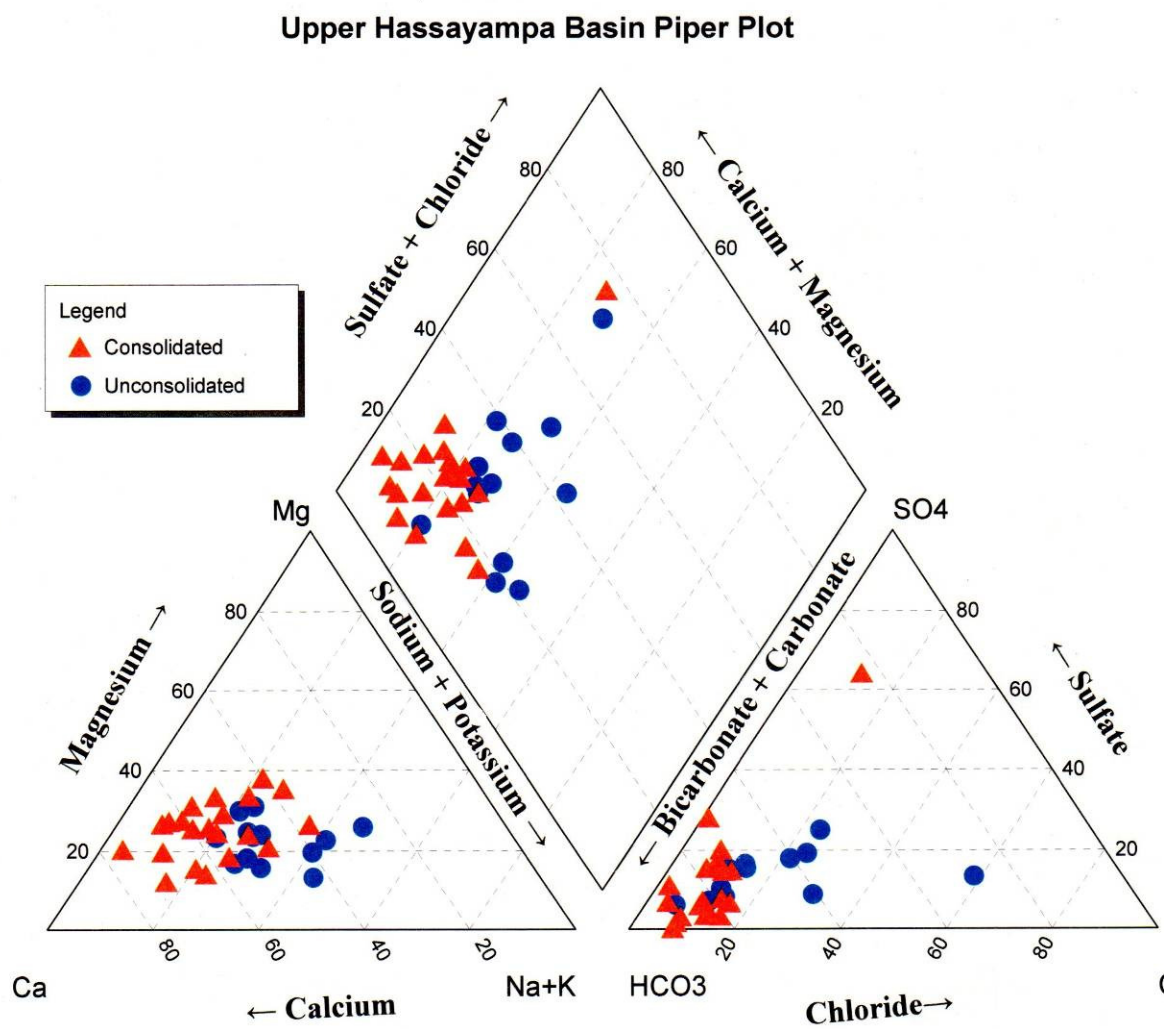
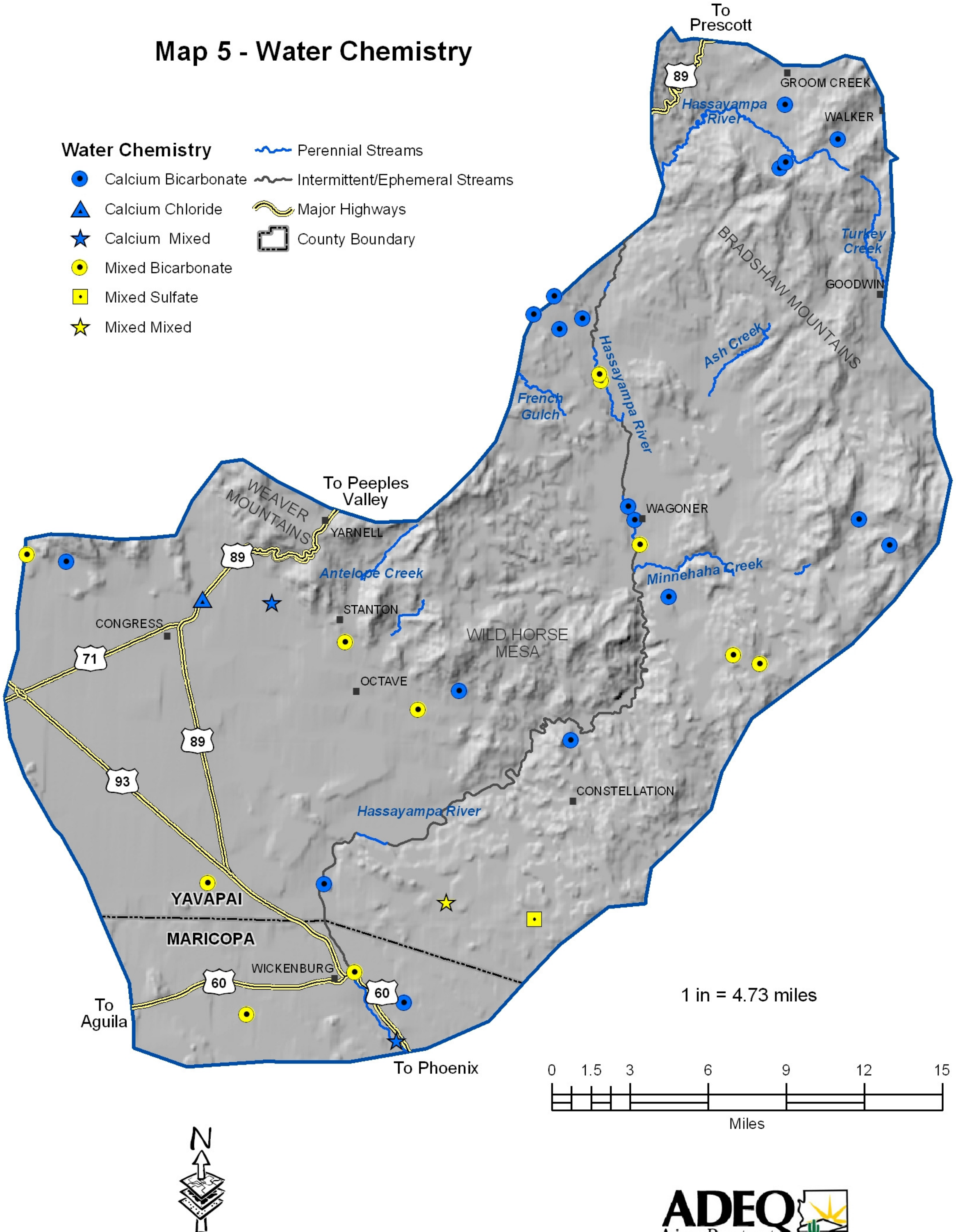


Diagram 2 – Samples collected in the Upper Hassayampa basin is predominantly a calcium-bicarbonate or mixed-bicarbonate chemistry which is reflective of young groundwater that has been recently recharged.[18]



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At 29 sites, levels of pH field were all *slightly alkaline* (above 7 su) and 2 sites were above 8 su. At 5 sites, pH-field levels were *slightly acidic* (below 7 su) [11]

TDS concentrations were considered *fresh* (below 999 mg/L) at 32 sites and slightly saline (1,000 – 3,000 mg/L) at 2 sites (Map 6).[11]

Hardness concentrations were *soft* (below 75 mg/L) at 0 sites, *moderately hard* (75 – 150 mg/L) at 2 sites, *hard* (150 – 300 mg/L) at 22 sites, *very hard* (300 - 600 mg/L) at 6 sites, and *extremely hard* (above 600 mg/L) at 2 sites (Map 7).[8]

Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities (Diagram 3). Nitrate concentrations were divided into natural background (8 sites at < 0.2 mg/L), may or may not indicate human influence (20 sites at 0.2 – 3.0 mg/L), may result from human activities (2 sites at 3.0 – 10 mg/L), and probably result from human activities (4 sites > 10 mg/L).[15]

Most trace elements such as aluminum, antimony, arsenic, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely – if ever - detected. Only barium, fluoride, and zinc were detected at more than 25 percent of the sites.

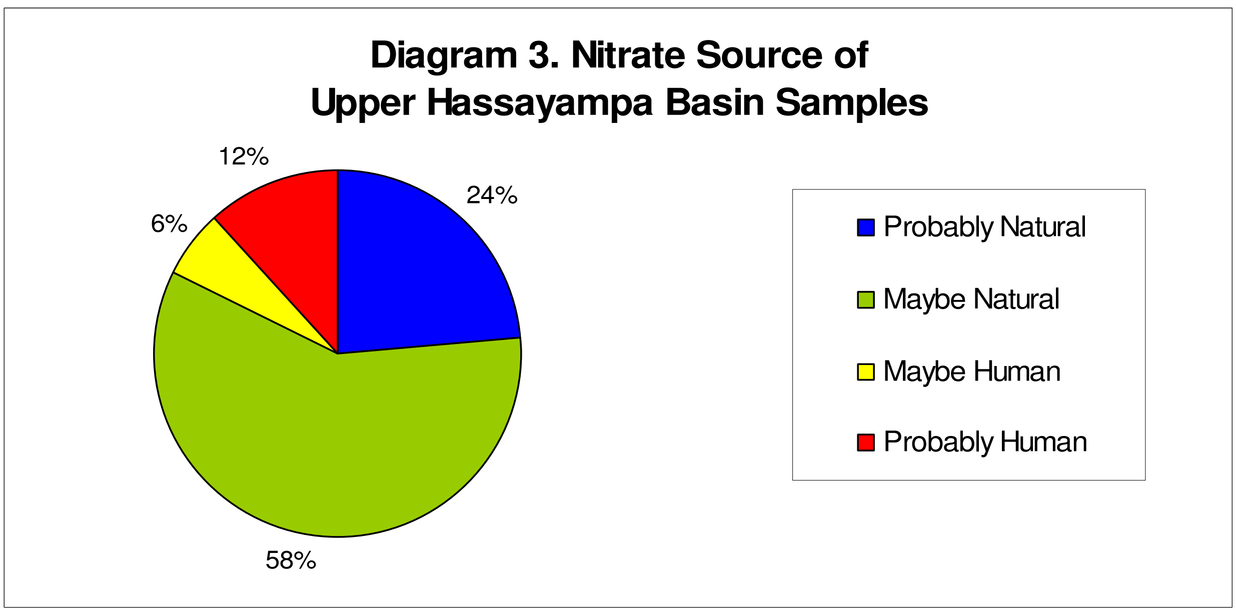
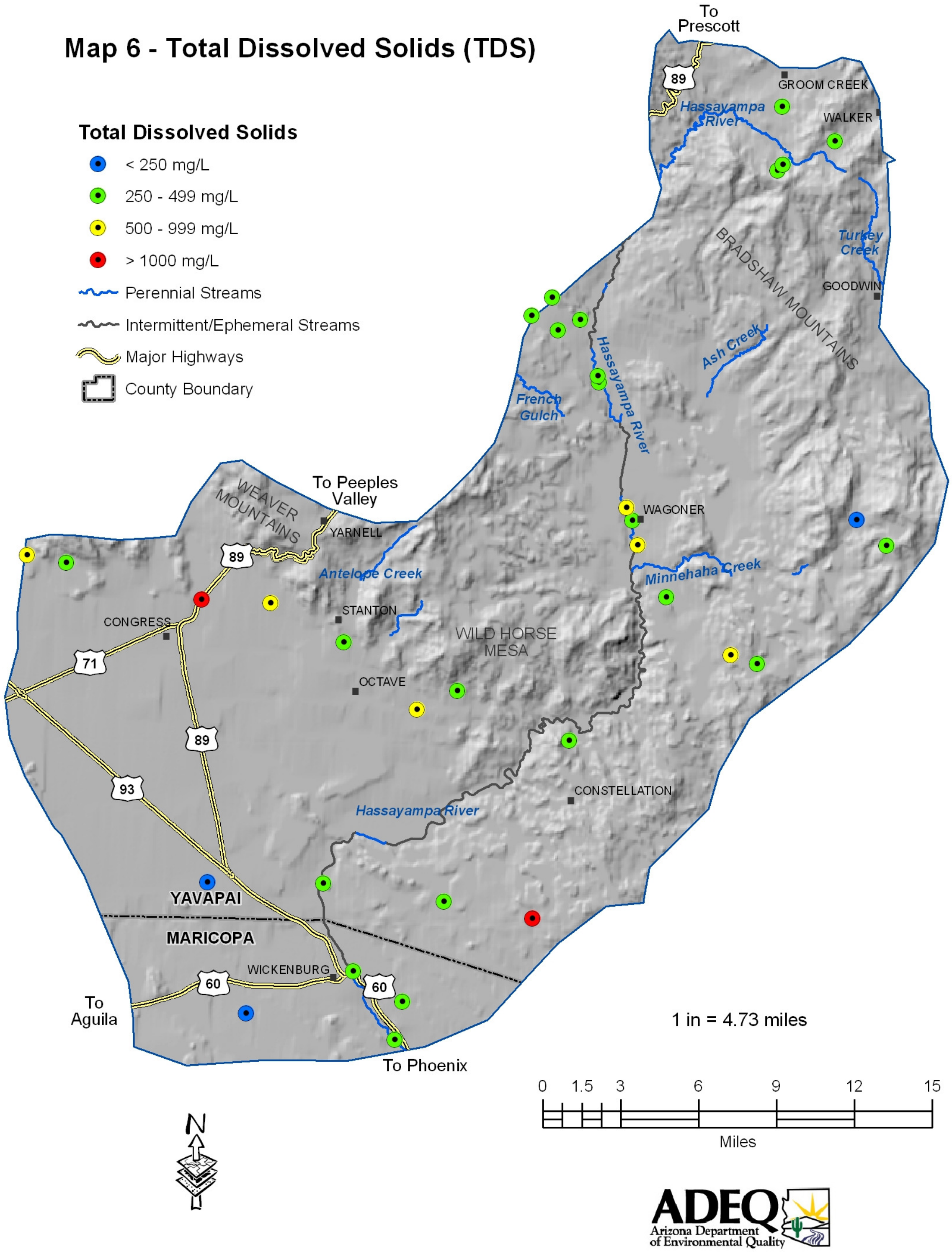
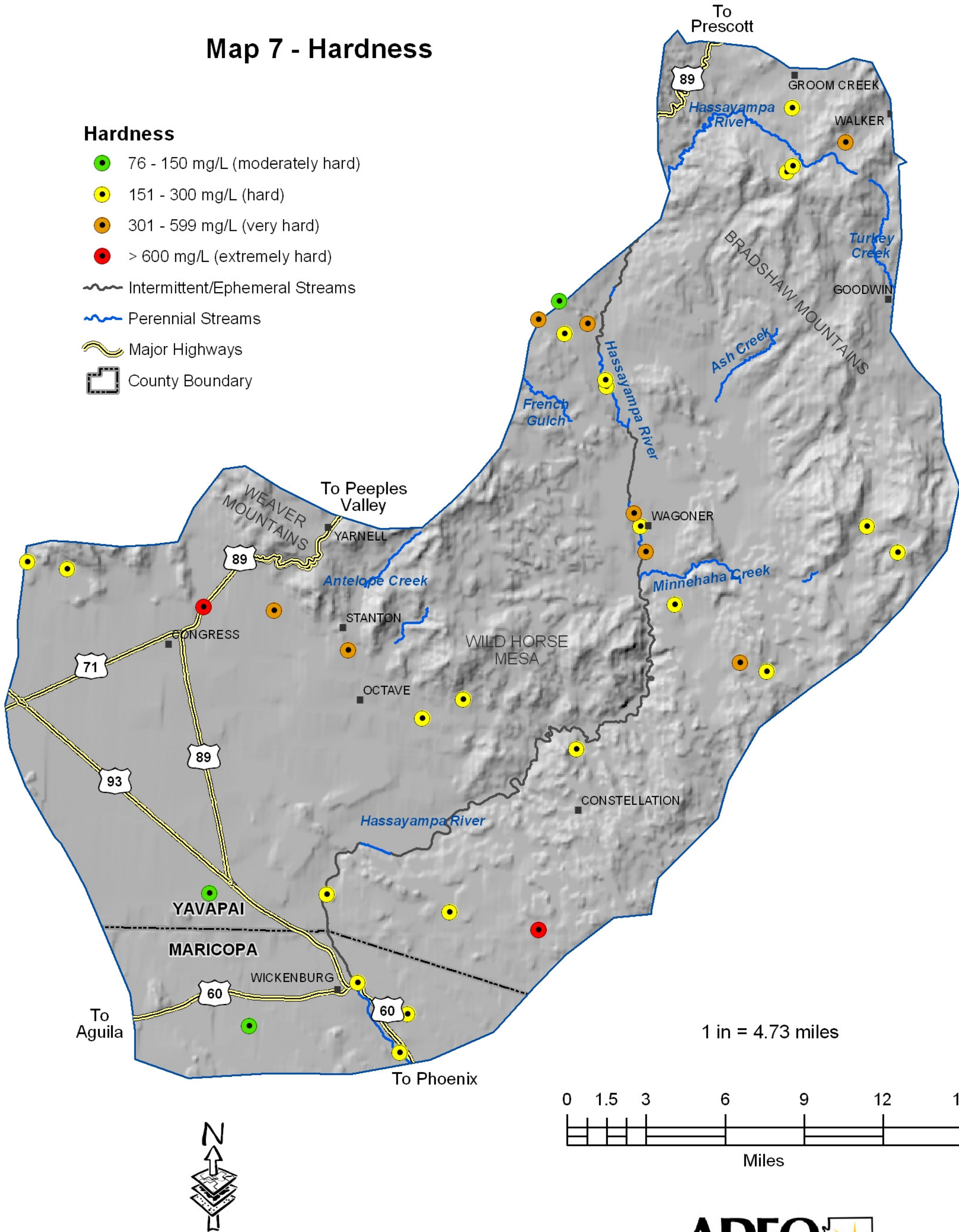


Diagram 3 – In the Upper Hassayampa basin, nitrate (as nitrogen) concentrations vary from non-detect (0.02 mg/L) to 19 mg/L. The Primary MCL for nitrate (as nitrogen) is 10 mg/L. Likely nitrogen sources for the basin's nitrate concentrations range from "probably natural" to "probably human" based on research published in a U.S. Geological Survey water supply paper. [15]


Map 6 - Total Dissolved Solids (TDS)
Total Dissolved Solids
< 250 mg/L
250 - 499 mg/L
500 - 999 mg/L
> 1000 mg/L
Perennial Streams
Intermittent/Ephemeral Streams
Major Highways
County Boundary
To Prescott
89
GROOM CREEK
Hassayampa River
WALKER
Turkey Creek
BRADSHAW MOUNTAINS
GOODWIN
Ash Creek
Hassayampa River
French Gulch
WEAVER MOUNTAINS
To Peeples Valley
YARNELL
WAGONER
Antelope Creek
Minnehaha Creek
STANTON
CONGRESS
WILD HORSE MESA
71
OCTAVE
89
93
CONSTELLATION
Hassayampa River
YAVAPAI
MARICOPA
WICKENBURG
60
60
To Aguila
To Phoenix
1 in = 4.73 miles
0 1.5 3 6 9 12 15
Miles
N
ADEQ
Arizona Department of Environmental Quality

Map 7 - Hardness



Constituent Co-Variation

The correlations between different chemical parameters were analyzed to determine the relationship between the constituents that were sampled. The strength of association between the chemical constituents allows for the identification of broad water quality patterns within a basin.

The results of each combination of constituents were examined for statistically-significant positive or negative correlations. A ***positive correlation*** occurs when, as the level of a constituent increases or decreases, the concentration of another constituent also correspondingly increases or decreases. A ***negative correlation*** occurs when, as the concentration of a constituent increases, the concentration of another constituent decreases, and vice-versa. A positive correlation indicates a direct relationship between constituent concentrations; a negative correlation indicates an inverse relationship.[27]

Several significant correlations occurred among the 34 sample sites (Table 8, Kendall's tau-b test, $p \leq 0.05$). Four groups of correlations were identified:

- The following constituents were all positively correlated with each other: TDS, SC, hardness, calcium, magnesium, sodium, bicarbonate (Diagram 4), chloride, sulfate, fluoride, and radon.

- Fluoride had a strong positive correlation with sodium and chloride.

- Nitrate was positively correlated with oxygen.

TDS concentrations are best predicted among major ions by calcium concentrations (standard coefficient = 0.37), among cations by calcium concentrations (standard coefficient = 0.52) and among anions, by bicarbonate concentrations (standard coefficient = 0.69) (multiple regression analysis, $p \leq 0.01$).

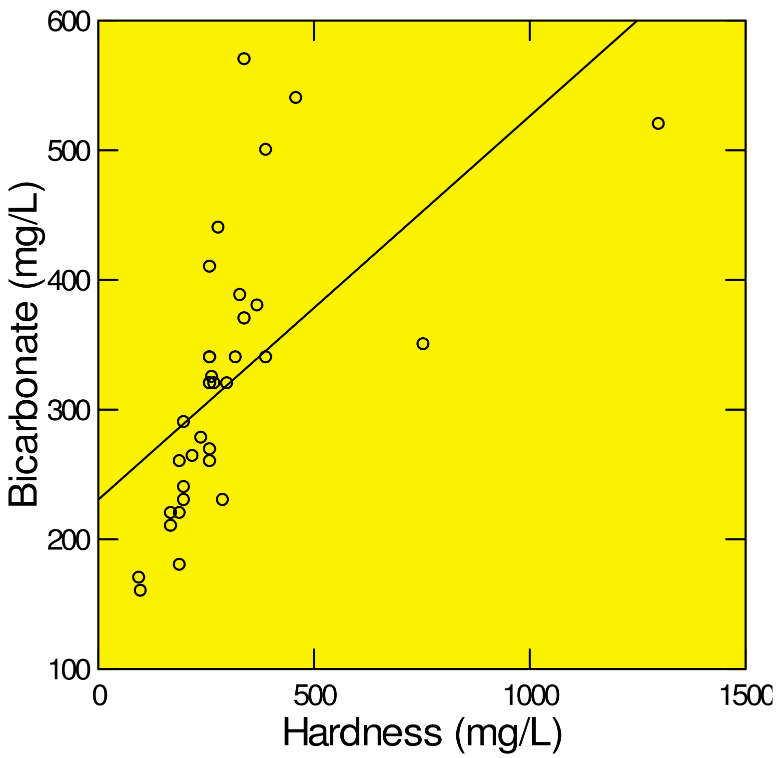


Diagram 4 – The graph illustrates a positive correlation between two constituents; as hardness concentrations increase, bicarbonate concentrations also increase. This relationship is described by the regression equation: $y = 0.30x + 231$ ($r = 0.60$). Both hardness and bicarbonate commonly occur in recharge areas and this relationship has been found in other Arizona groundwater basins.[18]

Table 8. Correlation Among Groundwater Quality Constituent Concentrations

Constituent	Temp	pH-f	pH-lab	SC-f	TDS	Hard	Ca	Mg	Na	K	Bic	Cl	SO_4	NO_3	F	Radon	O	D
Physical Parameters																		
Temperature									**	**		**	*	*	**		*	*
pH-field			*	++	++	++	++	++			++		+			++		
pH-lab					+	+	++					+						
SC-field					**	**	**	**	**		**	**	**		**	**		
General Mineral Characteristics																		
TDS						**	**	**	**		**	**	**		**	**		
Hardness							**	**	**		**	**	**		**	**		
Major Ions																		
Calcium								**	*		**	**	**			*		
Magnesium									**		**	**	**		*	**		
Sodium										**	**	**	**		**			
Potassium												*					*	*
Bicarbonate												**	*			**		
Chloride													**		**			
Sulfate															**	*		
Nutrients																		
Nitrate																	*	
Trace Elements																		
Fluoride																*		
Radioactivity																		
Radon																		
Isotopes																		
Oxygen																		**
Deuterium																		

Blank cell = not a significant relationship between constituent concentrations
* = Significant positive relationship at $p \leq 0.05$
** = Significant positive relationship at $p \leq 0.01$
+ = Significant negative relationship at $p \leq 0.05$
++ = Significant negative relationship at $p \leq 0.01$

Oxygen and Hydrogen Isotopes

The data for the Upper Hassayampa basin roughly conforms to what would be expected in an arid environment, having a slope of 5.0, with the Local Meteoric Water Line (LMWL) described by the linear equation: $\delta D = 5.0\delta\, ^{18}O - 27.7$ (Diagram 5). The LMWL for the Upper Hassayampa basin (5.0) is higher than a few other basins in Arizona such as Aravaipa Canyon (4.1) and Dripping Springs Wash (4.4). The basin is however, is lower than most other basins in Arizona including Detrital Valley (5.2), Agua Fria (5.3), Bill Williams (5.3), Sacramento Valley (5.5), Big Sandy (6.1), Butler Valley (6.4), Pinal Active Management Area (6.4), Gila Valley (6.4), San Simon (6.5), San Bernardino Valley (6.8), McMullen Valley (7.4), Lake Mohave (7.8), and Ranegras Plain (8.3). [23]

Isotope samples generally have values that reflect the elevation at which the sites were located. The five sample sites that are lowest along the LMWL have the lightest signatures from undergoing the least evaporation prior to sampling. These were collected at high elevations in the Bradshaw Mountains. Above these depleted samples are more enriched samples and appear to consist of recharge from lower-elevation precipitation that has undergone more evaporation prior to sampling. The most enriched samples on the graph were from shallow wells along the Hassayampa River. (Map 8).

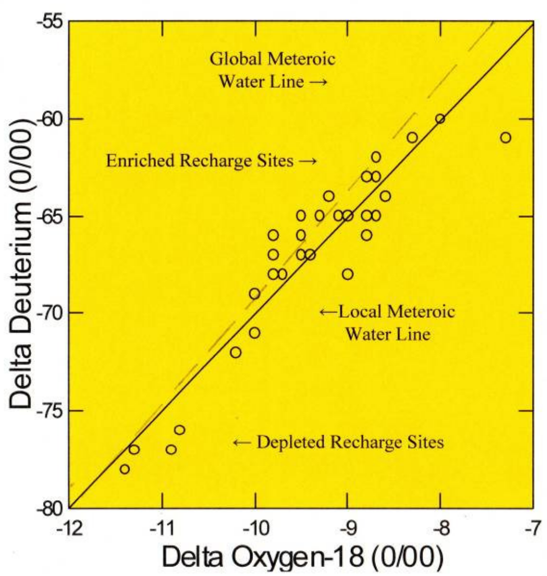


Diagram 5 – The 34 isotope samples are plotted according to their oxygen-18 and deuterium values and form the Local Meteoric Water Line.

Oxygen and Hydrogen Isotopes

Groundwater characterizations using oxygen and hydrogen isotope data may be made with respect to the climate and/or elevation where the water originated, residence within the aquifer, and whether or not the water was exposed to extensive evaporation prior to collection.[7] This is accomplished by comparing oxygen-18 isotopes ($\delta\, ^{18}O$) and deuterium (δD), an isotope of hydrogen, data to the Global Meteoric Water Line (GMWL). The GMWL is described by the linear equation:

$$\delta D = 8\, \delta\, ^{18}O + 10$$

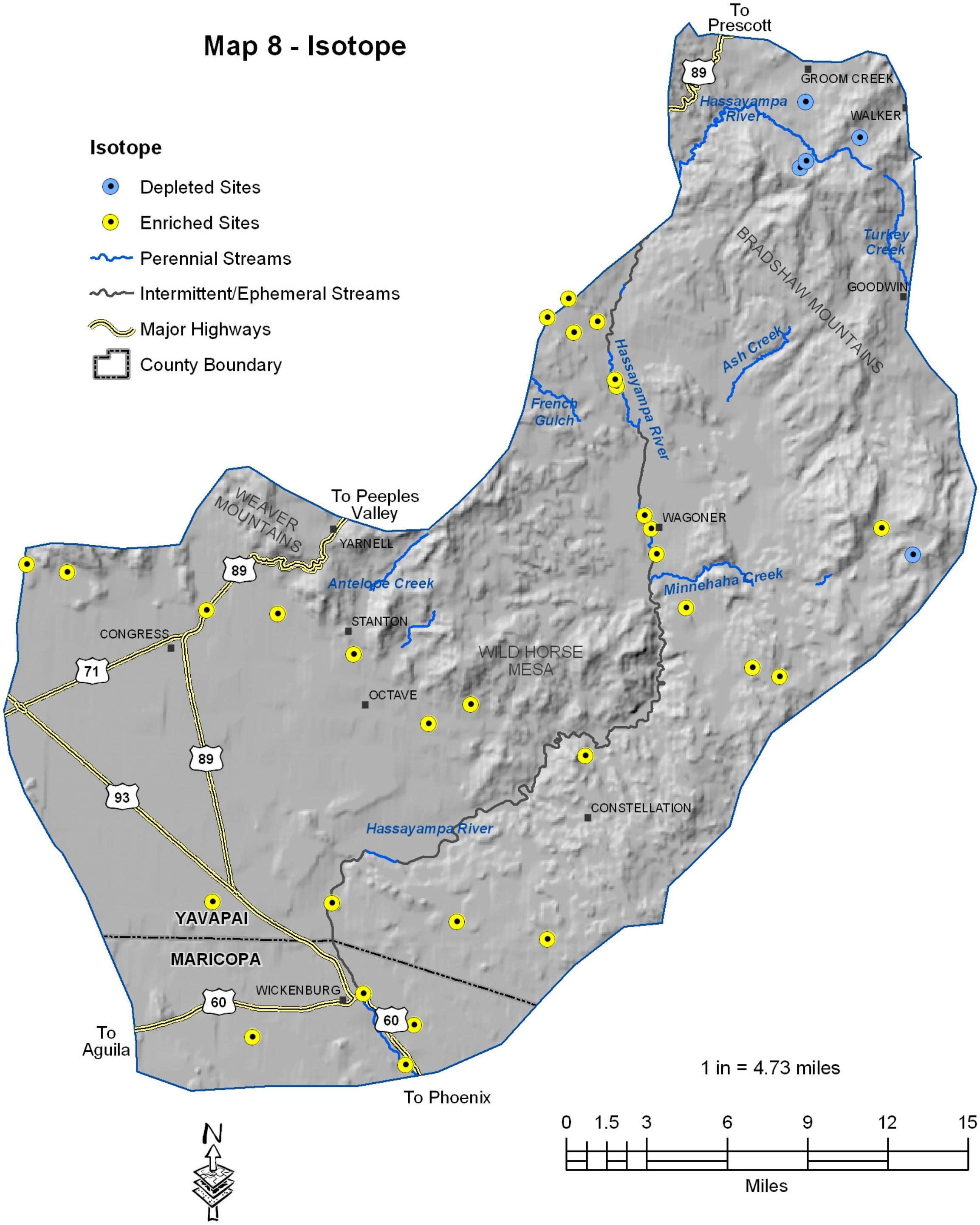
where δD is deuterium in parts per thousand (per mil, $^0/_{00}$), 8 is the slope of the line, $\delta\, ^{18}O$ is oxygen-18 $^0/_{00}$, and 10 is the y-intercept.[9] The GMWL is the standard by which water samples are compared and is a universal reference standard based on worldwide precipitation without the effects of evaporation.

Isotopic data from a region may be plotted to create a Local Meteoric Water Line (LMWL) which is affected by varying climatic and geographic factors. When the LMWL is compared to the GMWL, inferences may be made about the origin or history of the local water.[9] The LMWL created by $\delta\, ^{18}O$ and δD values for samples collected at sites in the Upper Hassayampa basin plot mostly to the right of the GMWL.

Meteoric waters exposed to evaporation are enriched and characteristically plot increasingly below and to the right of the GMWL. Evaporation tends to preferentially contain a higher percentage of lighter isotopes in the vapor phase and causes the water that remains behind to be isotopically heavier. In contrast, meteoric waters that experience little evaporation are depleted and tend to plot increasing to the left of the GMWL and are isotopically lighter. [7]

Groundwater from arid environments is typically subject to evaporation, which enriches δD and $\delta\, ^{18}O$, resulting in a lower slope value (usually between 3 and 6) as compared to the slope of 8 associated with the GMWL.[7]

Map 8 - Isotope



Groundwater Quality Variation

Between Two Recharge Groups – Twenty (20) groundwater quality constituents were compared between two recharge groups: enriched samples collected at lower elevations (15 sites) and depleted samples collected at higher elevations (5 sites).

Significant concentration differences were found with eight constituents: temperature, pH-lab, sodium (Diagram 6), potassium, chloride, fluoride (Diagram 7 and Map 9), oxygen-18 and deuterium (Kruskal-Wallis test, $p \leq 0.05$). In all these instances, sites with enriched samples had significantly higher constituent concentrations than sites with depleted samples.

Complete statistical results are in Table 9 and 95 percent confidence intervals for significantly different groups based on isotope recharge sources are in Table 10.

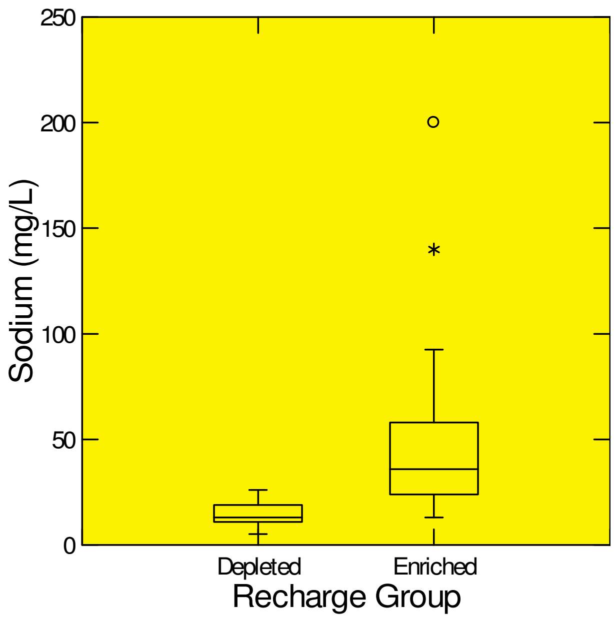


Diagram 6 – Sites consisting of enriched samples have significantly higher sodium concentrations than sites consisting of depleted samples (Kruskal-Wallis, $p \leq 0.05$). The depleted samples, collected at high elevations in the Bradshaw Mountains, have undergone the least evaporation prior to sampling. Recharge areas typically have low sodium concentrations though sodium often becomes the dominant cation in downgradient areas as a result of silicate weathering, halite dissolution, and ion exchange. [18]

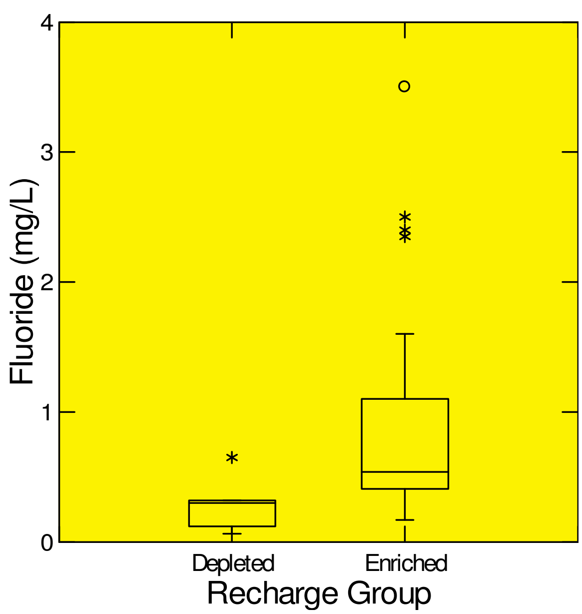


Diagram 7 – Sites consisting of enriched samples have significantly higher fluoride concentrations than sites consisting of depleted samples (Kruskal-Wallis, $p \leq 0.05$). Hydroxyl ion exchange provides control on fluoride concentrations below 5 mg/L. As groundwater pH values increase downgradient, greater levels of hydroxyl ions may affect an exchange of hydroxyl for fluoride ions thereby increasing the concentrations of fluoride in solution. [18]

Map 9 - Fluoride

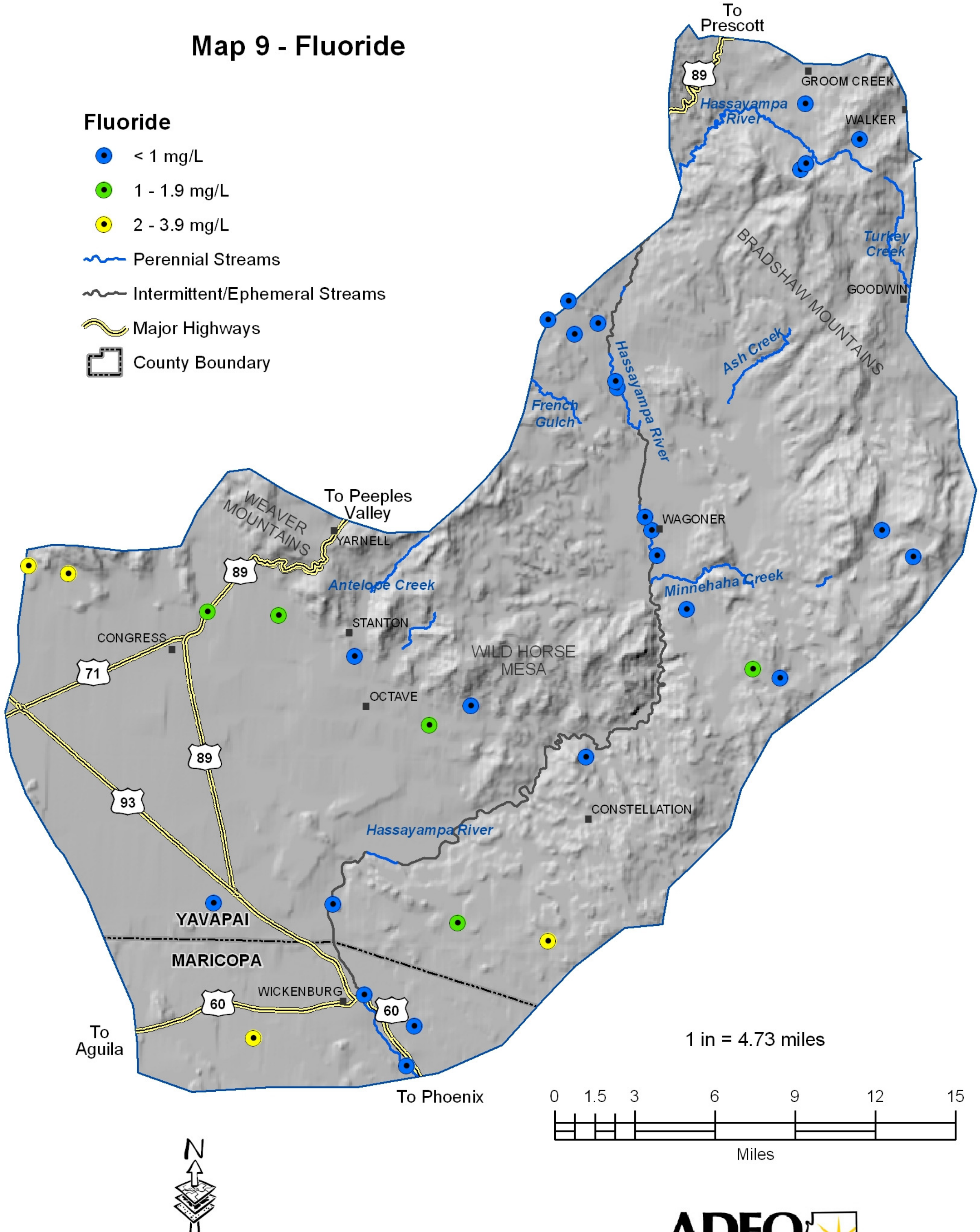


Table 9. Variation in Groundwater Quality Constituent Concentrations between Two Recharge Groups

Constituent	Significance	Significant Differences Between Recharge Groups
Temperature - field	*	Enriched > Depleted
pH – field	ns	-
pH – lab	*	Enriched > Depleted
SC - field	ns	-
SC - lab	ns	-
TDS	ns	-
Turbidity	ns	-
Hardness	ns	-
Calcium	ns	-
Magnesium	ns	-
Sodium	**	Enriched > Depleted
Potassium	*	Enriched > Depleted
Bicarbonate	ns	-
Chloride	**	Enriched > Depleted
Sulfate	ns	-
Nitrate (as N)	ns	-
Fluoride	*	Enriched > Depleted
Radon	ns	-
Oxygen	**	Enriched > Depleted
Deuterium	**	Enriched > Depleted

ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level

Table 10. Summary Statistics for Two Recharge Groups with Significant Constituent Differences

Constituent	Significance	Depleted	Enriched
Temperature – field (°C)	*	8.7 to 22.4	18.8 to 22.9
pH – field (su)	ns	-	-
pH – lab (su)	*	6.94 to 7.87	7.61 to 7.86
SC - field (µS/cm)	ns	-	-
SC - lab (µS/cm)	ns	-	-
TDS	ns	-	-
Turbidity	ns	-	-
Hardness	ns	-	-
Calcium	ns	-	-
Magnesium	ns	-	-
Sodium	**	5 to 25	35 to 66
Potassium	*	-0.9 to 4.4	2.0 to 3.4
Bicarbonate	ns	-	-
Chloride	**	-2 to 26	21 to 80
Sulfate	ns	-	-
Nitrate (as N)	ns	-	-
Fluoride	*	0.0 to 0.6	0.6 to 1.2
Radon	ns	-	-
Oxygen (0/00)	**	-11.4 to -10.7	-9.40 to -8.91
Deuterium (0/00)	**	-77.8 to -75.8	-66.7 to -64.5

ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
All units are mg/L except where indicated.

Between Two Geologic Groups - Twenty groundwater quality constituents were compared between two broad geologic types: consolidated crystalline rock (16 sites) and unconsolidated sediments (18 sites).[4, 16, 19]

Significant concentration differences were found with seven constituents: temperature, turbidity, sodium, sulfate, nitrate (Diagram 8 and Map 10), fluoride, and deuterium (Kruskal-Wallis test, $p \leq 0.05$). In addition, pH-field (Diagram 9) and oxygen-18 both narrowly missed being significant. All constituents except for turbidity had significantly higher concentrations in samples collected from unconsolidated sediment than from consolidated rock.

Complete statistical results are in Table 11 and 95 percent confidence intervals for significantly different groups based on recharge groups are in Table 12.

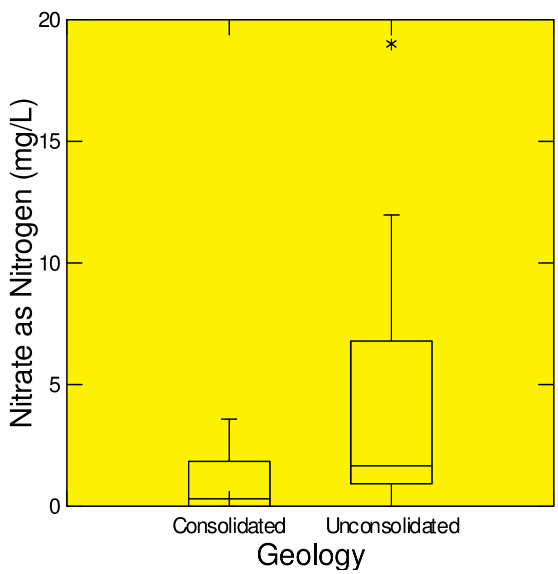


Diagram 8 – Samples collected from sites in unconsolidated sediments have significantly higher nitrate concentrations than sample sites collected from consolidated rock (Kruskal-Wallis, $p \leq 0.05$). This pattern may be due to increased residential and commercial development that has occurred in basin-fill areas.

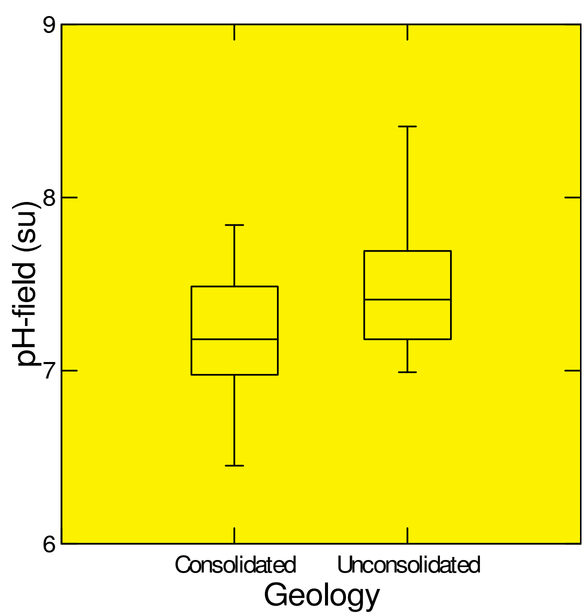


Diagram 9 – Samples collected from sites in unconsolidated sediments have significantly higher pH-field values than samples collected from consolidated rock (Kruskal-Wallis, $p \leq 0.05$). In areas of consolidated rock, acidic precipitation averaging 5.8 su percolates into faults and crevices. The recharged groundwater gradually increases in pH downgradient through silicate hydrolysis reactions. [18]

Map 10 - Nitrate

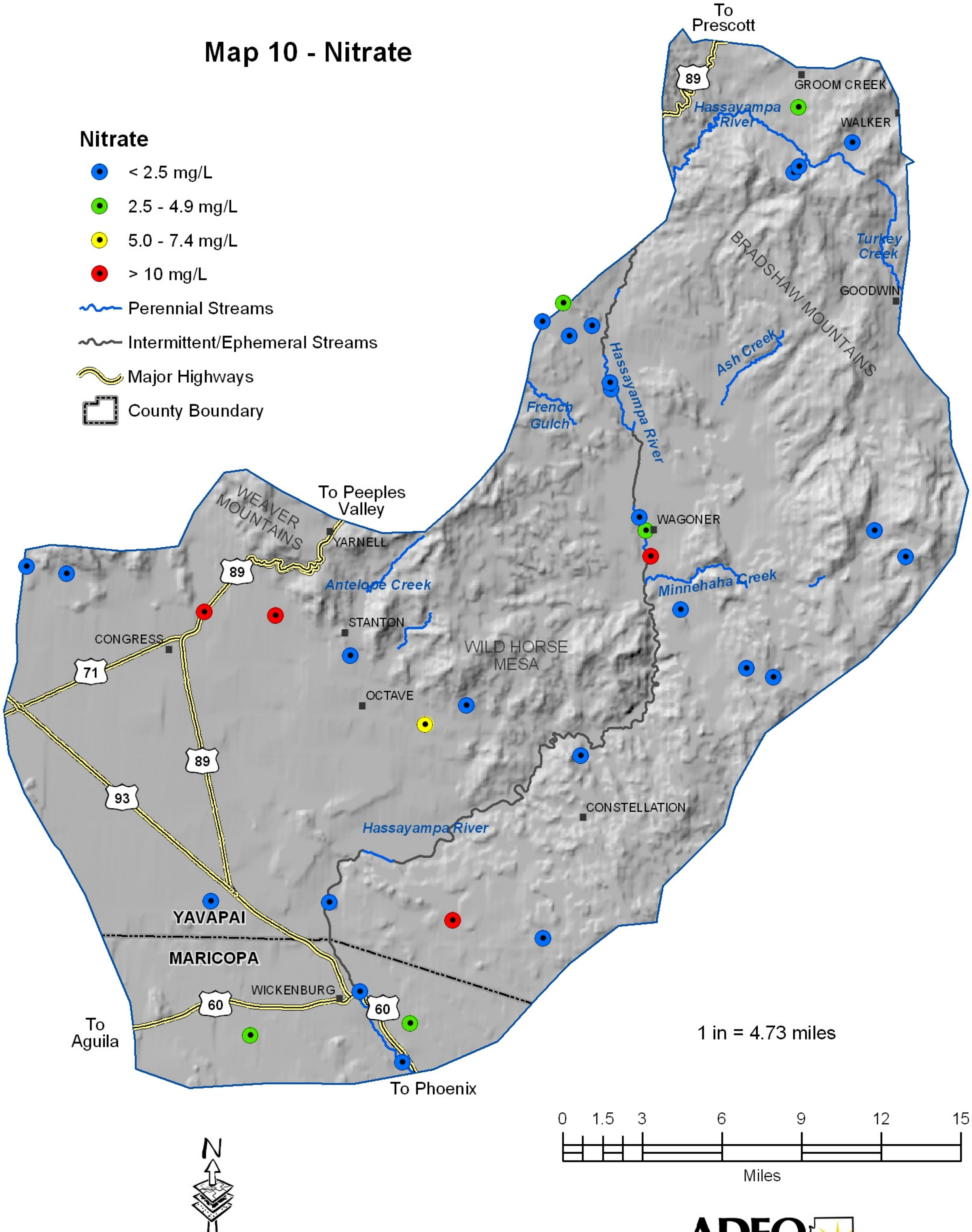


Table 11. Variation in Groundwater Quality Constituent Concentrations between Two Geologic Groups

Constituent	Significance	Significant Differences Between Geologic Types
Temperature - field	**	Unconsolidated Sediment > Consolidated Rock
pH – field	almost	Unconsolidated Sediment > Consolidated Rock
pH – lab	ns	-
SC - field	ns	-
SC - lab	ns	-
TDS	ns	-
Turbidity	*	Consolidated Rock > Unconsolidated Sediment
Hardness	ns	-
Calcium	ns	-
Magnesium	ns	-
Sodium	**	Unconsolidated Sediment > Consolidated Rock
Potassium	ns	-
Bicarbonate	ns	-
Chloride	ns	-
Sulfate	*	Unconsolidated Sediment > Consolidated Rock
Nitrate (as N)	**	Unconsolidated Sediment > Consolidated Rock
Fluoride	**	Unconsolidated Sediment > Consolidated Rock
Radon	ns	-
Oxygen	almost	Unconsolidated Sediment > Consolidated Rock
Deuterium	*	Unconsolidated Sediment > Consolidated Rock

ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level

Table 12. Summary Statistics for Two Geologic Groups with Significant Constituent Differences

Constituent	Significance	Consolidated Rock	Unconsolidated Sediments
Temperature – field (°C)	**	14.7 to 20.4	19.7 to 24.7
pH – field (su)	ns	7.00 to 7.41	7.28 to 7.66
pH – lab (su)	ns	-	-
SC – field (µS/cm)	ns	-	-
SC – lab (µS/cm)	ns	-	-
TDS	ns	-	-
Turbidity	*	1.9 to 13.4	-5.5 to 20.2
Hardness	ns	-	-
Calcium	ns	-	-
Magnesium	ns	-	-
Sodium	**	12 to 63	36 to 67
Potassium	ns	-	-
Bicarbonate	ns	-	-
Chloride	ns	-	-
Sulfate	*	-51 to 237	38 to 73
Nitrate (as N)	**	0.3 to 1.6	1.7 to 7.0
Fluoride	**	0.2 to 0.8	0.6 to 1.5
Radon	ns	-	-
Oxygen (0/00)	ns	-10.4 to -9.2	-9.4 to -8.9
Deuterium (0/00)	*	-72.6 to -66.5	-66.5 to 64.0

ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
All units mg/L except where indicated.

DISCUSSION

Groundwater in the Upper Hassayampa basin is generally suitable for drinking water uses based on the water quality results from sampling conducted for this study. Samples from 20 of the 34 sites met all water quality standards. [25] Moreover, samples from four other sites had only minor exceedances of aesthetics-based standards for TDS, iron, and/or manganese, making 24 of the 34 sample sites (71 percent) generally acceptable as a drinking water source.

Of the remaining 10 sample sites, the constituents that most commonly impacted the acceptability of water for drinking purposes were gross alpha and nitrate. These are two of the four constituents that most commonly exceed health-based water quality standards in Arizona. [22]

Gross alpha exceeded health-based, water quality standards in radionuclide samples collected from five sites. Radionuclide samples were collected however, at only 12 of the 34 sites, so gross alpha had a 42 percent water quality exceedance rate. This finding is not unexpected as much of the basin consists of granitic geology which is associated with elevated radionuclide concentrations in groundwater.[14] Furthermore, some sites such as Coyt Well (UHA-6) also had inactive mines nearby which are strongly connected with elevated radionuclide concentrations.[14] Uranium concentrations did not exceed water quality standards but these were tested for in only 3 of the 12 radionuclide samples. All gross alpha exceedances occurred in wells or springs that are used for livestock watering. Future groundwater quality studies in the basin should better characterize gross alpha concentrations by collecting additional radionuclide samples.

Nitrate exceeded health-based, water quality standards in samples collected from four wells. Three of the exceedances were just over the 10.0 mg/L nitrate (as nitrogen) standard (11, 11 and 12 mg/L) while a sample from the remaining well was almost double the standard at 19 mg/L. Potential sources of nitrate vary by site.

- The sample (UHA-11) collected at the Parker Dairy Farm Well is likely due to livestock waste from the agricultural operation. Although the well serving the dairy is 1,050 feet deep, the groundwater depth and screened interval are unknown.
- The sample (UHA-21) collected at the remote Cooper Ranch could be due to discharges from septic systems as the shallow well was reportedly only 40 feet deep with a water level of 14 feet bls.
- The sample (UHA-19) collected from the Arrowhead Bar in Congress could also be from septic system discharge, particularly with the greater waste stream created from a commercial business as well as other nearby residences on septic systems in the historic mining town. This conclusion is supported by the sample having a TDS concentration of 1,350 mg/L and a chloride concentration of 420 mg/L, both of which are also indicators of septic system discharge.[28] Both of these concentrations exceeded their respective aesthetics-based water quality standards. Furthermore, the TDS concentration is the second highest in the basin and is much greater than the median TDS concentration of 410 mg/L. The chloride concentration is the highest in the basin and greatly exceeds the median chloride concentration of 26 mg/L. The well serving the Arrowhead Bar is 700 feet deep, has a screened interval from 520 to 700 feet, and has an unknown groundwater depth.
- The sample (UHA-5) collected from Sky Camp Well had the highest nitrate (as nitrogen) concentration in the basin at 19 mg/L. The former windmill that is now powered by a generator and submersible pump is located about four miles northwest of Wickenburg along Constellation Road. The depth of well is not known; perhaps waste from livestock watering at the well contributed to the high nitrate concentration.

The only other site which had an exceedance of a health-based water quality standard was a sample (UHA-1) collected from the Flying E Ranch. The 440-feet-deep well had the highest arsenic and fluoride concentrations in the basin; the concentrations of these two constituents are frequently significantly correlated in other Arizona groundwater basins.[21] The sample's arsenic concentration of 0.01 mg/L equaled the health-based water quality standard. The sample's fluoride concentration of 3.5 mg/L did not exceed the 4.0 health-based standard but exceeded the 2.0 mg/L aesthetics-based standard. The sample also had the highest pH-field value of 8.41 su, just below the aesthetics-based standard and some of softest water (100 mg/L) recorded in the study. The sample chemically appears more similar to groundwater samples collected in the Forepaugh aquifer located in the bordering McMullen Valley basin. [21]

Fluoride concentrations in groundwater are often controlled by calcium through precipitation or dissolution of the mineral, fluorite. In a chemically closed hydrologic system, calcium is removed from solution by precipitation of calcium carbonate and the formation of smectite clays. Concentrations exceeding 5 mg/L of dissolved fluoride may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution.[18] The site however, is only partially depleted in calcium and appears to be controlled by processes other than fluorite dissolution.

Hydroxyl ion exchange or sorption-desorption reactions have also been cited as providing controls on lower (< 5 mg/L) levels of fluoride. As pH values increase downgradient, greater levels of hydroxyl ions may affect an exchange of hydroxyl for fluoride ions thereby increasing fluoride in solution. [18] The pH levels of the sample (UHA-1) appear to follow this pattern with a pH-field value of 8.41 su.

In common with fluoride, arsenic concentrations are effected by reactions with hydroxyl ions. Elevated arsenic concentrations are also influenced by factors such as aquifer residence time, an oxidizing environment, and lithology. [18]

Another sample (UHA-6) with unusual water chemistry was collected from Coyt Well located in a remote area about six miles east of Wickenburg. The sample exceeded health-based water quality standards for gross alpha and aesthetics-based water quality standards for TDS, sulfate, fluoride, and manganese. The sample collected from the site had the highest concentrations of TDS (2,300 mg/L) and sulfate (1,100 mg/L) found in the basin. Based on these results, the water quality exceedances appear to be influenced by the nearby historic mining activity. [18] Especially notable is the sulfate result which is almost nine times the next highest concentration found in the basin. The presence of relatively high concentrations of iron, manganese, and TKN combined with a non-detection of nitrate suggest unusual reducing conditions in groundwater produced by the well. [18] The groundwater results from this well appear to be site specific and probably are not reflective of regional groundwater conditions.

In the basin, there is some tendency for constituent concentrations to be significantly higher in groundwater sites collected in unconsolidated sediment and/or which consist of enriched recharge. These trends however, do not impact the acceptability of these sites for use as a drinking water source.

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Appendix A. Data for Sample Sites, Upper Hassayampa Basin, 2003-2009

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Perforation Interval
				1st Field Trip, February 11, 2003 – Boettcher & Lucci					
UHA-1	B(7-5)17cca submersible	33°56'48.139" 112°47'39.010"	630737	19004	Flying E Ranch HQ	Inorganic, Radon O & H Isotopes	440'	374'	-
UHA-2/2D duplicate	B(8-5)23dbb submersible	34°01'12.432" 112°44'38.130"	561978	60581	East of HouseWell	Inorganic, Radon O & H Isotopes	200'	70'	140-200'
UHA-3/3S split	B(8-6)24dad	34°01'10.722" 112°49'18.238"	571452	19334	Moreton Well	Inorganic, Radon O & H Isotopes	415'	338'	315-415'
UHA-4	B(7-4)17aba submersible	33°57'17.312" 112°41'21.549"	548766	60582	Glinski Well	Inorganic, Radiochem O & H Isotopes	355'	225'	250-350'
				2nd Field Trip, April 10, 2003 - Boettcher & Lucci					
UHA-5	B(8-4)27bbd submersible	34°00'40.631" 112°39'45.065"	634092	19325	Sky Camp Well	Inorganic, Radiochem O & H Isotopes	-	-	-
UHA-6	B(8-3)30dda submersible	34°00'08.472" 112°36'11.544"	801554	60670	Coyt Well	Inorganic, Radiochem O & H Isotopes	-	-	-
UHA-7/7D duplicate	B(10-7)23aaa windmill	34°12'02.745" 112°12'02.270"	614626	19672	Yellow Well	Inorganic O & H Isotopes	-	-	-
				3rd Field Trip, March 22-23, 2003 – Towne & Boettcher					
UHA-8/9 partial duplicate	B(9-4)16cad submersible	34°07'05.382" 112°40'58.080"	609871	62635	Moralez Well	Inorganic, Radiochem Radon, Isotopes	17'	10'	-
UHA-10	B(9-4)10ddd spring	34°07'45.267" 112°39'24.343"	-	61081	Sinoski Spring	Inorganic, Radiochem Isotopes	-	-	-
UHA-11	B(10-5)28bad submersible	34°10'35.049" 112°46'56.582"	520743	61091	Parker Dairy Farm	Inorganic, Radiochem Isotopes	1050'	-	-
UHA-12	B(12.5-2)35cbd submersible	34°25'22.425" 112°26'44.400"	545809	61095	Rebb Well	Inorganic, Radiochem Isotopes	160'	20'	60-160'
UHA-13	B(12.5-2)35bdc submersible	34°25'34.508" 112°26'31.090"	642867	61096	Norris Well	Inorganic, Radiochem Isotopes	450'	40'	-
UHA-14	Hassayampa River At Greg's	-	-	-	-	Isotope	-	-	-
UHA-15	B(11-3)5bba submersible	34°19'54.054" 112°35'31.271"	649183	61097	Curie Well	Inorganic Isotopes	100'	15'	-
UHA-16/17a split	B(7-4)20caa submersible	33°55'59.930" 112°41'38.520"	535404	55072	Hassya.Rvr Preserve W	Inorganic Isotopes	200'	19'	120-200'
UHA-16a	Hassayampa River at Preserve	-	-	-	-	Isotope	-	-	-
				4th Field Trip, June 9-11, 2003 – Boettcher & Lucci					
UHA-17b	B(9-3)21cdb spring	34°06'08.7" 112°44'08.6"	-	19495	House Spring	Inorganic, Radon O & H Isotopes	-	-	-
UHA-18	B(10-6)19bda windmill		614622	19659	Buck's Windmill	Inorganic, Radiochem Isotopes	-	100'	-
UHA-19/19S split	B(10-6)25bdb submersible	34°10'39.433" 112°49'44.716"	586443	62690	Arrowhead Bar Well	Inorganic, Radon O & H Isotopes	700'	300'	520-700'
UHA-20	B(9-5)1bbd submersible	34°08'59.189" 112°44'05.223"	643463	19501	Grantham Well	Inorganic, Radon O & H Isotopes	180'	155'	-
UHA-21	B(10-3)14ada submersible	34°12'43.714" 112°32'09.492"	624338	19640	Cooper RanchWell	Inorganic, Radon O & H Isotopes	40'	14'	-
UHA-22/22D duplicate	B(12-4)36aac windmill	34°20'40.116" 112°37'17.301"	614675	67661	Walker Place Mill	Inorganic, Radon O & H Isotopes	222'	150'	-
UHA-23	B(13-2)35bc submersible		632365	62618	YMCA Camp Well	Inorganic Isotopes	-	-	-
UHA-25	B(12.5-1)30bdb spring		-	62607	Boundary Spring	Inorganic, Radon O & H Isotopes	-	-	-

Appendix A. Data for Sample Sites, Upper Hassayampa Basin, 2003-2009---Continued

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Perforation Interval
5th Field Trip, February 22, 2007 – Towne & Smart (Travel Blank AGF-58)									
UHA-26	B(10-1)16bba spring	34°12'49.383" 112°22'06.701"	-	67580	Senator Spring	Inorganic, Radiochem Radon, Isotopes	-	-	-
UHA-27	B(10-1)8bad spring	34°13'40.294" 112°23'20.570"	-	67581	Patterson Spring	Inorganic Isotopes	-	-	-
UHA-28	B(9-2)3dcb windmill	34°08'48.273" 112°27'16.125"	633348	67582	Up Oak Ck Windmill	Inorganic, Radiochem Radon, Isotopes	65'	12'	-
UHA-29	B(9-2)4acc windmill	34°09'05.415" 112°28'20.136"	633349	62606	ML Windmill	Inorganic, Radiochem Radon, Isotopes	60'	20'	-
6th Field Trip, March 7, 2007 – Towne & Boettcher									
UHA-30	Hassayampa River at Wagoner Rd	-	-	-	-	Isotope	-	-	-
UHA-31	B(12-3)33c spring	34°20'15.473" 112°34'37.056"	-	67662	Collins Spring	Inorganic Isotopes	-	-	-
7th Field Trip, September 18, 2008 – Towne & Mitchell (Equipment Blank - MMU-121)									
UHA-32	B(7-5)1ddc bailer	33°58'17.305" 112°43'24.076"	588564	71762	MW-5	Inorganic, Radiochem Isotopes	35'	22'	15-35'
8th Field Trip, January 21, 2009 – Towne (Travel Blank, BWM- 85)									
UHA-33	B(10-2)30bbc spring	34°10'59.775" 112°31'00.725"	-	72861	Campbell Flat Spring	Inorganic, Isotopes	-	-	-
UHA-34	Minnehaha Creek at Wagoner Road	-	-	-	-	Isotope	-	-	-
UHA-35	B(10-3)11acd submersible	34°13'33.418" 112°32'25.470"	628604	19636	Diamond Two House	Inorganic, Radon Isotopes	328'	10'	-
UHA-36	B(10-3)2cdd submersible	34°13'59.450" 112°32'41.269"	901948	72862	Z Triangle House Wl	Inorganic, Isotopes	142'	21'	102-142'
UHA-37	B(11-3)15bba submersible	34°18'10.730" 112°33'51.911"	506299	19724	TK Bar Ranch Wl	Inorganic, Radon Isotopes	300'	60'	-
UHA-38	B(11-3)10ccb submersible	34°18'23.676" 112°33'55.279"	622261	72863	TK Bar Rn Artesian	Inorganic, Radon Isotopes	575'	100'	-
UHA-39	B(12-3)30bdd windmill	34°21'17.595" 112°36'39.893"	601427	72864	Hackberry Windmill	Inorganic, Isotopes	252'	230'	-

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009---Continued

Site #	MCL Exceedances	Temp (°C)	pH-field (su)	pH-lab (su)	SC-field (µS/cm)	SC-lab (µS/cm)	TDS (mg/L)	Hard (mg/L)	Hard - cal (mg/L)	Turb (ntu)
UHA-1	As, F	24.5	8.41	*8.0*	321	350	220	100	100	*0.06*
UHA-2/2D	-	20.1	7.87	*7.75*	493	540	315	200	205	0.075
UHA-3/3S	-	26.5	8.11	*7.9*	332	360	200	96	93	0.26
UHA-4	-	26.3	7.61	*7.5*	443	480	300	190	200	0.04
UHA-5	NO_3	24.0	7.69	*7.5*	772	800	450	290	280	*3.2*
UHA-6	TDS, SO_4 F, Mn, Gross α	21.9	6.92	*7.2*	2738	2900	**2300**	1300	1100	32
UHA-7/7D	TDS, F, Gross α	23.2	7.60	*7.5*	908	935	**580**	265	260	11.5
UHA-8/9	TDS	20.1	7.02	7.4	874	870	**530**	260	250	0.27
UHA-10	-	-	-	*7.6*	744	700	410	260	250	0.62
UHA-11	TDS, NO_3 Gross α	29.4	7.26	*7.4*	1189	1200	**710**	390	390	0.22
UHA-12	-	12.7	6.45	*7.0*	522	520	290	260	270	5.4
UHA-13	-	12.6	6.83	*7.4*	481	460	260	220	230	7.9
UHA-15	-	18.3	6.91	*7.5*	589	590	330	260	280	ND
UHA-16	-	24.2	7.34	*7.715*	692	670	410	240	260	ND
UHA-17	-	23.3	7.66	*8.0*	641	650	390	260	270	35
UHA-18	F, Fe, Gross α	25.7	7.48	*7.0*	718	710	440	260	270	0.96
UHA-19/19S	TDS, Cl, NO_3 Radon	26.6	6.99	*7.39*	2191	2200	**1350**	755	800	2.65
UHA-20	-	24.8	7.19	*7.4*	826	830	490	330	340	ND
UHA-21	TDS, NO_3 Radon	19.3	7.15	*7.5*	1168	1100	**700**	460	480	0.34
UHA-22/22D	-	18.5	7.36	*7.4*	643	647	395	320	320	0.75
UHA-23	-	15.8	7.84	*7.4*	470	490	280	200	220	4.2
UHA-25	Radon	25.0	7.18	*7.2*	764	770	440	340	360	0.48
UHA-26	Mn, Radon	11.7	7.12	*8.0*	718	630	360	270	310	14
UHA-27	Fe, Mn	8.1	7.18	*8.0*	468	340	240	170	170	6.8
UHA-28	Radon	17.9	7.03	*8.0*	804	720	420	280	280	1.8
UHA-29	TDS, Gross α Radon	17.3	7.04	*8.1*	1003	920	**560**	340	330	4.4
UHA-31	Mn	15.2	7.28	*8.0*	946	780	470	390	360	7.3
UHA-32	-	21.2	7.28	*8.0*	715	660	420	260	250	110

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009---Continued

Site #	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	T. Alk (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
UHA-1	25	9.5	31	3.1	130	160	ND	13	11
UHA-2/2D	55	16.5	31	2.45	200	240	ND	23	38
UHA-3/3S	20	11.5	37	3.65	140	170	ND	17.5	14
UHA-4	56	14	21	3.4	210	260	ND	9.6	14
UHA-5	75	28	36	2.8	190	230	ND	66	26
UHA-6	340	100	200	6.6	430	520	ND	150	**1100**
UHA-7/7D	80.5	15	92.5	1.9	265	325	ND	79	86
UHA-8/9	73	21.5	83	1.5	340	410	ND	37	43
UHA-10	80	16	40	2.0	280	340	ND	40	23
UHA-11	120	22	84	3.3	280	340	ND	90	130
UHA-12	86	14	5.2	0.61	243	269	ND	3.9	27
UHA-13	65	17	11	ND	216	264	ND	6.7	16
UHA-15	76	21	16	1.6	260	320	ND	17	8.9
UHA-16	67	20.5	44	2.65	234	278	ND	31.5	51.5
UHA-17	88	12	35	3.4	280	340	ND	38	11
UHA-18	83	15	45	0.82	210	260	ND	53	60
UHA-19/19S	235	48.5	140	8.75	295	350	ND	**420**	130
UHA-20	82	34	48	1.6	318	388	ND	46	67
UHA-21	98	56	77	6.6	440	540	ND	51	86
UHA-22/22D	91.85	22.95	13	1.3	280	340	ND	30	11
UHA-23	57	19	13	1.1	190	230	ND	23	18
UHA-25	86	34	26	5.5	300	370	ND	25	66
UHA-26	97	17	19	1.2	270	320	ND	ND	100
UHA-27	44	15	17	2.1	170	210	ND	11	33
UHA-28	79	21	58	3.0	360	440	ND	32	30
UHA-29	76	33	84	3.1	470	570	ND	53	21
UHA-31	100	26	28	0.81	410	500	ND	26	ND
UHA-32	69	20	42	2.2	260	320	ND	28	52

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Nitrate-N (mg/L)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phosphorus (mg/L)	SAR (value)	Irrigation Quality	Cyanide (ug/L)	Aluminum (mg/L)
UHA-1	2.7	ND	0.054	ND	ND	1.3	C2-S1	-	ND
UHA-2/2D	1.05	ND	ND	ND	0.050	0.9	C2-S1	-	ND
UHA-3/3S	0.94	ND	ND/1.1	ND	ND	1.6	C2-S1	-	ND
UHA-4	2.9	ND	ND	ND	ND	0.7	C2-S1	-	ND
UHA-5	**19**	ND	0.054	ND	ND	0.9	C3-S1	-	ND
UHA-6	ND	ND	0.19	-	0.023	2.5	C4-S1	-	ND
UHA-7/7D	1.6	ND	ND/.82	-	0.0285	2.5	C3-S1	-	ND
UHA-8/9	6.8	0.022	0.30	ND	0.035	2.2	C3-S1	-	ND
UHA-10	0.42	ND	0.059	ND	ND	1.1	C2-S1	-	ND
UHA-11	**12**	ND	0.19	ND	ND	1.8	C3-S1	-	ND
UHA-12	0.12	ND	0.062	ND	0.053	0.1	C2-S1	-	ND
UHA-13	1.2	ND	ND	ND	0.042	0.3	C2-S1	-	ND
UHA-15	1.6	ND	ND	ND	0.032	0.4	C2-S1	ND	ND
UHA-16	1.5	ND	0.095	ND	0.074	1.2	C2-S1	-	ND
UHA-17	0.24	ND	0.18	0.064	0.077	0.9	C2-S1	-	ND
UHA-18	0.40	ND	0.055	ND	ND	1.2	C2-S1	-	ND
UHA-19/19S	**11**	ND	.40/.17	ND/0.68	ND	2.2	C4-S1	-	ND
UHA-20	0.85	ND	ND	ND	ND	1.1	C3-S1	-	ND
UHA-21	**11**	ND	0.35	ND	0.16	1.5	C3-S1	-	ND
UHA-22/22D	2.15	ND	0.155	ND	0.0445	0.3	C2-S1	-	ND
UHA-23	2.9	ND	0.060	ND	ND	0.4	C2-S1	-	ND
UHA-25	ND	ND	ND	ND	ND	0.6	C1-S1	-	ND
UHA-26	ND	ND	ND	-	0.02	0.6	C3-S1	-	-
UHA-27	ND	ND	ND	-	0.03	0.5	C2-S1	-	-
UHA-28	0.31	ND	0.13	-	0.02	0.6	C2-S1	-	-
UHA-29	0.15	ND	0.06	-	ND	1.5	C2-S1	-	-
UHA-31	ND	ND	0.10	-	ND	2.0	C3-S1	-	-
UHA-32	1.7	ND	ND	ND	0.40	0.6	C3-S1	-	-

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Antimony (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Beryllium (mg/L)	Boron (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Fluoride (mg/L)
UHA-1	ND	**0.010**	ND	ND	0.12	ND	0.035	ND	**3.5**
UHA-2/2D	ND	ND	ND	ND	ND	ND	ND	ND	0.41
UHA-3/3S	ND	ND	ND	ND	ND	ND	0.032	ND	0.41
UHA-4	ND	ND	ND	ND	ND	ND	ND	ND	0.29
UHA-5	ND	ND	0.22	ND	ND	ND	ND	ND	1.0
UHA-6	ND	ND	ND	ND	0.19	ND	ND	ND	**2.5**
UHA-7/7D	ND	ND	ND	ND	0.14	ND	ND	ND/.011	**2.35**
UHA-8/9	ND	ND	0.20	ND	0.105	ND	ND	0.10	1.1
UHA-10	ND	ND	0.24	ND	ND	ND	ND	ND	0.34
UHA-11	ND	ND	ND	ND	ND	ND	ND	ND	1.6
UHA-12	ND	ND	ND	ND	ND	ND	ND	0.065	0.064
UHA-13	ND	ND	ND	ND	ND	ND	ND	ND	0.12
UHA-15	ND	ND	ND	ND	ND	ND	ND	ND	0.24
UHA-16	ND	ND	ND	ND	0.12	ND	ND	0.12	0.615
UHA-17	ND	ND	0.43	ND	ND	ND	ND	ND	0.49
UHA-18	ND	ND	ND	ND	ND	ND	ND	0.017	**2.4**
UHA-19/19S	ND	ND	0.0.96	ND	ND	ND	ND	ND	1.2
UHA-20	ND	ND	ND	ND	ND	ND	ND	ND	0.66
UHA-21	ND	ND	ND	ND	0.20	ND	ND	ND	0.58
UHA-22/22D	ND	ND	ND	ND	ND	ND	ND	ND	0.25
UHA-23	ND	ND	0.30	ND	ND	ND	ND	ND	0.30
UHA-25	ND	ND	ND	ND	ND	ND	ND	ND	0.32
UHA-26	ND	ND	ND	ND	ND	ND	ND	ND	0.65
UHA-27	ND	ND	ND	ND	ND	ND	ND	ND	0.17
UHA-28	ND	ND	ND	ND	ND	ND	ND	ND	0.62
UHA-29	ND	ND	ND	ND	ND	ND	ND	ND	1.2
UHA-31	ND	0.0084	0.10	ND	ND	ND	ND	ND	0.54
UHA-32	ND	ND	0.077	ND	0.13	ND	ND	ND	0.52

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Iron (mg/L)	Lead (mg/L)	Manganese (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Silver (mg/L)	Thallium (mg/L)	Zinc (mg/L)
UHA-1	ND	ND	ND	ND	ND	ND	ND	ND	0.077
UHA-2/2D	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-3/3S	ND	ND	ND	ND	ND	ND	ND	ND	0.145
UHA-4	ND	ND	ND	ND	ND	ND	ND	ND	0.78
UHA-5	ND	ND	ND	ND	ND	ND	ND	ND	0.51
UHA-6	0.29	ND	**1.5**	ND	ND	ND	ND	ND	0.081
UHA-7/7D	ND	ND	ND	ND	ND	ND	ND	ND	3.45
UHA-8/9	ND	ND	ND	ND	**0.12/ND**	ND	ND	ND	ND
UHA-10	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-11	ND	ND	ND	ND	ND	ND	ND	ND	0.56
UHA-12	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-13	ND	ND	ND	ND	ND	ND	ND	ND	0.22
UHA-15	ND	ND	ND	ND	ND	ND	ND	ND	0.13
UHA-16	ND	ND	ND	ND	**0.25/ND**	ND	ND	ND	ND
UHA-17	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-18	**0.48**	ND	ND	ND	ND	ND	ND	ND	2.2
UHA-19/19S	ND	ND	ND	ND	ND	ND/.0097	ND	ND	1.1
UHA-20	ND	ND	ND	ND	ND	ND	ND	ND	0.21
UHA-21	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-22/22D	ND	ND	ND	ND	ND	ND	ND	ND	0.41/ND
UHA-23	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-25	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-26	0.29	ND	**0.12**	ND	ND	ND	ND	ND	ND
UHA-27	**0.95**	ND	**0.063**	ND	ND	ND	ND	ND	ND
UHA-28	ND	ND	ND	ND	ND	ND	ND	ND	0.078
UHA-29	ND	ND	ND	ND	ND	ND	ND	ND	0.20
UHA-31	ND	ND	**0.53**	ND	ND	ND	ND	ND	ND
UHA-32	ND	ND	ND	ND	ND	ND	ND	ND	ND

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	*^{18} O ($^{0}/_{00}$)	* D ($^{0}/_{00}$)	Type of Chemistry
UHA-1	244	-	-	-	-	- 8.8	- 63	mixed-bicarbonate
UHA-2/2D	229	-	-	-	-	- 8.3	- 61	calcium-bicarbonate
UHA-3/3S	135	-	-	-	-	- 9.2	- 64	mixed-bicarbonate
UHA-4	-	5.4	ND	-	-	- 8.7	- 65	calcium-bicarbonate
UHA-5	-	9.6	ND	-	-	- 8.0	- 60	mixed-mixed
UHA-6	-	**41**	ND	-	-	- 8.7	- 62	mixed-sulfate
UHA-7/7D	-	**42**	ND	-	-	- 10.0	- 71	mixed-bicarbonate
UHA-8/9	218	2.5	ND	ND	-	- 9.0	- 65	mixed-bicarbonate
UHA-10	-	2.3	ND	ND	-	- 10.2	- 72	calcium-bicarbonate
UHA-11	-	**30**	ND	ND	-	- 9.5	- 67	calcium-mixed
UHA-12	-	3.4	ND	ND	-	- 11.3	- 77	calcium-bicarbonate
UHA-13	140	2.1	ND	ND	-	- 11.4	- 78	calcium-bicarbonate
UHA-14	-	-	-	-	-	- 11.1	- 77	-
UHA-15	-	-	-	-	-	- 8.6	- 64	calcium-bicarbonate
UHA-16	-	-	-	-	-	- 9.1	- 65	mixed-bicarbonate
UHA-16A	-	-	-	-	-	- 8.9	- 64	-
UHA-17	< 47	-	-	-	-	- 9.4	- 67	calcium-bicarbonate
UHA-18	-	**75**	6.5	ND	-	- 9.7	- 68	calcium-bicarbonate
UHA-19/19S	**547**	-	-	-	-	- 8.8	- 65	calcium-chloride
UHA-20	224	-	-	-	-	- 8.7	- 63	mixed-bicarbonate
UHA-21	**775**	-	-	-	-	- 8.8	- 66	mixed-bicarbonate
UHA-22/22D	276	-	-	-	-	**- 7.3**	**- 61**	calcium-bicarbonate
UHA-23	-	-	-	-	-	- 10.8	- 76	calcium-bicarbonate
UHA-24	-	-	-	-	-	**- 9.9**	**- 73**	-
UHA-25	**1186**	-	-	-	-	- 10.8	- 76	calcium-bicarbonate
UHA-26	**1083**	6.1	3.0	1.8	-	- 10.9	- 77	calcium-bicarbonate
UHA-27	-	-	-	-	-	- 9.8	- 66	calcium-bicarbonate
UHA-28	**1412**	6.6	8.2	ND	-	- 9.5	- 66	mixed-bicarbonate
UHA-29	**2641**	**20**	8.4	ND	14	- 9.8	- 68	mixed-bicarbonate

LLD = Lower Limit of Detection

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009---Continued

Site #	MCL Exceedances	Temp (°C)	pH-field (su)	pH-lab (su)	SC-field (µS/cm)	SC-lab (µS/cm)	TDS (mg/L)	Hard (mg/L)	Hard - cal (mg/L)	Turb (ntu)
UHA-33	-	8.7	7.49	*8.0*	530	500	310	200	210	1.2
UHA-35	Radon	15.1	7.18	*8.0*	719	700	430	300	300	0.01
UHA-36	TDS	-	7.09	*8.0*	825	800	**500**	370	350	1.3
UHA-37	Radon	20.2	7.62	*8.2*	499	470	290	170	190	0.16
UHA-38	-	24.2	7.69	*8.2*	501	480	330	190	190	0.01
UHA-39	-	18.4	7.68	8.1	400	370	250	150	160	1.2

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	T. Alk (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
UHA-33	68	10	24	1.5	240	290	ND	15	4.2
UHA-35	82	22	33	1.2	260	320	ND	23	54
UHA-36	97	27	34	1.8	310	380	ND	24	68
UHA-37	40	23	24	1.8	180	220	ND	18	34
UHA-38	44	20	23	1.9	180	220	ND	13	48
UHA-39	54	5.6	13	2.2	150	180	ND	13	10

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Nitrate-N (mg/L)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phosphorus (mg/L)	SAR (value)	Irrigation Quality	Cyanide (ug/L)	Aluminum (mg/L)
UHA-33	ND	*ND*	0.13	ND	ND	0.7	C2-S1	-	-
UHA-35	2.9	*ND*	ND	ND	ND	0.8	C2-S1	-	-
UHA-36	2.4	ND	*ND*	ND	ND	0.8	C3-S1	-	-
UHA-37	1.3	ND	*ND*	ND	ND	0.7	C2-S1	-	-
UHA-38	0.90	ND	*ND*	ND	ND	0.7	C2-S1	-	-
UHA-39	3.6	ND	*ND*	ND	ND	0.5	C2-S1	-	-

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Antimony (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Beryllium (mg/L)	Boron (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Fluoride (mg/L)
UHA-33	ND	ND	0.011	ND	ND	ND	ND	ND	0.36
UHA-35	ND	ND	0.050	ND	0.13	ND	ND	ND	0.46
UHA-36	ND	ND	0.060	ND	0.12	ND	ND	ND	0.42
UHA-37	ND	ND	0.022	ND	ND	ND	0.013	ND	0.51
UHA-38	ND	0.0062	0.021	ND	ND	ND	ND	ND	0.56
UHA-39	ND	ND	0.018	ND	ND	ND	ND	ND	0.18

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Iron (mg/L)	Lead (mg/L)	Manganese (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Silver (mg/L)	Thallium (mg/L)	Zinc (mg/L)
UHA-33	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-35	ND	ND	ND	ND	ND	ND	ND	ND	0.050
UHA-36	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-37	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-38	ND	ND	ND	ND	ND	ND	ND	ND	ND
UHA-39	ND	ND	ND	ND	ND	ND	ND	ND	0.88

Appendix B. Groundwater Quality Data, Upper Hassayampa Basin, 2003-2009--Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	$*^{18}$O ($^0/_{00}$)	$*$D ($^0/_{00}$)	Type of Chemistry
UHA-30	-	-	-	-	-	- 9.3	- 67	-
UHA-31	-	-	-	-	-	- 9.0	- 68	calcium-bicarbonate
UHA-32	-	2.5	2.1	-	-	- 9.1	- 65	mixed-bicarbonate
UHA-33	-	-	-	-	-	- 9.4	- 67	calcium-bicarbonate
UHA-34	-	-	-	-	-	- 8.8	- 59	-
UHA-35	**320**	-	-	-	-	- 9.5	- 67	calcium-bicarbonate
UHA-36	-	-	-	-	-	- 9.5	- 65	calcium-bicarbonate
UHA-37	**389**	-	-	-	-	- 9.3	- 65	mixed-bicarbonate
UHA-38	154	-	-	-	-	- 9.8	- 67	mixed-bicarbonate
UHA-39	-	-	-	-	-	- 10.0	- 69	calcium-bicarbonate

LLD = Lower Limit of Detection